ELEMENTARY CHEMISTRY.

BARFF

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PREFACE.

THIS book, as far as it goes, professes to enable the attentive student to acquire a sound knowledge of the very elementary facts concerning the most important of the "non-metallic elements," as they are called. It is written for young boys of ordinary abilities, who understand arithmetic as far as proportion or rule of three. The writer's object is to ensure such a *sound* grounding in Chemical Science, that the knowledge acquired will enable the student to go on a step further, and easily understand symbolical notation and the more difficult facts concerning the bodies which he has studied; or, should any boy who has learnt what is taught in this book go no further, that he may still have a *useful* though but a limited knowledge of Chemistry. A further, and, as he believes a still more im-

portant object, the writer has had in view, namely, the mental training of young boys, who will, he hopes, by the system he has adopted, have their reasoning faculties strengthened, and their powers of observation rendered accurate and acute. From some experience in teaching boys, the writer believes that at first they should not be compelled to commit names and quantities to memory, but should be required to observe the experimental illustrations carefully, and that they should be required to explain the experiments and apparatus, even though they cannot recollect the names or proportions of the substances employed. They should, however, have their properties impressed on their minds. By this is meant that they should know, for example, that in making hydrogen a metal is used, and an acid, or some liquid which contains hydrogen, and that the hydrogen comes from it, not from the metal or from the water, and that the water is used to dissolve the solid formed when the hydrogen has gone away, or when potassium or sodium are made to act on water. If they forget the names of the metals at first, no matter; they should, however, be made to recollect that they are soft, lighter than metals generally are, that when exposed to air their metallic lustre is soon dimmed by a white

film, and what follows when they are thrown into water. A number of questions for calculation are given in Chapter XVI.; if these are worked out, pupils will soon learn without effort the proportionate numbers in which the substances treated of combine, and by constant reference to the chapters where these are treated of, which will be necessary in order to work the questions out, they will soon get accustomed to the names, and will recollect them without effort. In order to ensure the use of language which could be understood by boys, the writer dictated most of the chapters to one of his pupils at the middle school, who took them down in shorthand from his dictation; the boy who did this was a thoughtful boy of about thirteen years old, and any phrase used which he could not understand, was so changed as to make it intelligible to him. By adopting this course the writer hopes that he has adapted his instructions to the capacities of the general run of boys. Chapter XV. is devoted to an explanation of the illustrations, with instructions how to set up apparatus.

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ELEMENTARY CHEMISTRY.

CHAPTER I.

ACTION OF HEAT ON ICE.

IF you put a lump of ice into a suitable vessel and apply heat, the ice will not get any warmer, but it will melt. This can be proved by the following experiment (Fig. 1):— Take a beaker-glass and put it over a lamp, and into it place some broken ice; in the centre of the ice put the bulb of a thermometer, and screen the thermometer so that it cannot become heated from the side. The mercury in the thermometer will remain all the time at one point, which is called Zero, till all the ice becomes melted. When the ice is melted the water will begin to rise in temperature, if the source of the

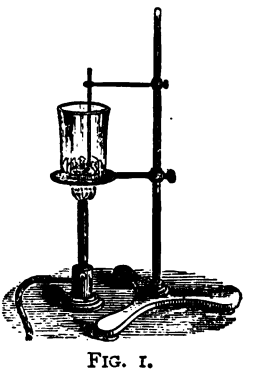

FIG. 1.

heat be not taken away, and it will go on getting hotter until the mercury in the thermometer rises to 100°. The thermometer here used is a Centigrade thermometer, but if a Fahrenheit thermometer be employed the mercury will stand in it at 32°, when first placed in the ice, and then will rise to 212°, when the water begins to boil.

Action of Heat on Water.—If the thermometer

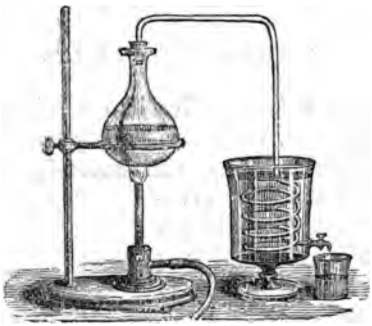

FIG. 2.

be left in the water, and the heat be still applied, the mercury will rise no higher, and all the water will boil away, being converted into steam. Suppose instead of allowing the steam to escape, such a vessel be used that the steam can be made to pass through a spiral tube surrounded by cold water, contained in a suitable vessel (Fig. 2), the steam will become water again, and in passing through the cold water will give out heat, so that the cold water will

become warm. If the vessel containing the water, formed by the condensed steam, be surrounded by ice and salt, the water will again become ice. You see that the changes effected first in the ice and then in the water are due to the action of heat. But the heat did not raise the temperature of the ice, it only changed it into water, and the water remained water so long as the heat, which was put into it, remained in it. Again, the steam remained steam as long as the heat, which changed the water into steam, remained in the steam. This is proved by the fact that when the steam is passed through the cooled tube it gives up its heat to the water with which the tube was surrounded, and itself becomes water; and we see by the conclusion of the experiment that when the heat, which was originally put into the ice and converted it into water, is withdrawn, by a freezing mixture of ice and salt the water becomes ice again.

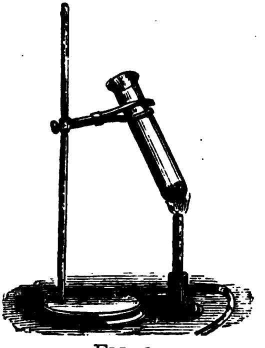

FIG. 3.

Action of Heat on Iodine.—If you put into the glass tube, such as is shown in Fig. 3, a few grains of a solid substance called iodine, and if you warm it gradually the iodine will melt, and will remain for a very short time liquid; provided the tube be not

removed from the source of heat, the iodine will shortly become a gas, and will indicate its presence by its beautiful violet colour. If you now withdraw the tube from the source of heat, the purple-coloured gas will disappear, and the sides of the tube will be covered with pieces of solid iodine, in appearance exactly like that which was originally put into the tube, only they will be much smaller.

Action of Heat on Brimstone.—Suppose now we take a piece of brimstone, and put it into a tube similar to that used in the last experiment. If we gently heat the tube the brimstone will melt, and if we go on applying heat, the brimstone will become a gas of a brownish-red colour. If the tube be allowed to cool, the brimstone will again appear, deposited in small pieces on the sides of the tube.

The Three States in which Matter exists.—Now, these three experiments teach us the states in which the substances which we shall have to treat of exist. They are three—viz., solid, liquid, and gaseous; and we learn that it is heat which can change solid substances into liquid, and by its longer continued action can also change, in many instances, liquids into gases.

You will remember that the ice, when heat was applied, got no hotter until it was all melted. Here the heat acted upon the ice, but it did not make itself known as heat; it acted in another way—it caused the ice to change its state. So that it is

sometimes said that a liquid is a solid with the addition of heat, and that a gas is also a liquid with the addition of heat; and that while that heat remains in the liquid or in the gas those substances retain their liquid or gaseous states. You will understand by-and-by the more scientific explanation of this.

It is quite necessary, before entering upon the study of Chemistry, that you should have a correct idea of these three states in which substances exist. We are accustomed to speak of these substances generally as matter, and in future I shall use that word.

Matter is something which can be weighed.—Many explanations are given of what matter is; but when the word is used in this book you will understand that I am speaking of something which has weight. Now, gases have weight as well as solids and liquids, for if you take a bladder, or an india-rubber air-ball, and weigh it very carefully, and then if you allow the air to escape and you weigh it, it will weigh less, when it contains no air, than when it was full of air. Now the air is a mixture of several gases, as you will learn in the chapter on the atmosphere.

Physical Action.—This *temporary* action which heat exerts on matter is called a physical action.

Chemical Action.—In Chemistry we study the changes which take place when substances are so mixed together that they act upon one another and

form new substances, which differ altogether from those which produced them. Now two things may be mixed and remain quite unchanged in their composition—there is here no chemical action. This will be explained fully in a future chapter.

We have seen that heat acts upon certain bodies, and only changes the state in which they exist, the bodies remaining chemically the same, and that they can be brought back to their original state. But heat changes many substances so that we cannot restore them again to their original state. Thus, for example, if a piece of wood be heated to a high temperature it ceases to be wood, and we have no power, if we collect the substances which are formed from it, when heated, of putting them together again so as to make wood. When *heat* produces this effect, or when it causes bodies to change their composition, the action it produces is called *chemical*.

CHAPTER II.

WATER.

WATER, as you know, is a liquid. There are different sorts of water to be met with, such as pump-water, river-water, rain-water, and sea-water. The differences between these will be explained by-and-by. All of them consist of pure water with the addition of certain other things, which make them impure. And now first, let us consider

what *pure* water is. In the winter time, when the weather is very cold, it is a solid; generally it is a liquid. Water is not a simple substance. By this is meant that it contains more substances than one, and it can be separated into them.

Elements.—Simple substances, which cannot be separated into others, are called *elements;* and those which are made up of two or more elements are called compound substances. Water, therefore, is a compound substance.

Composition of Water.—Suppose some pure water be placed in a suitable vessel, and suppose two wires terminated by pieces of platinum, the wires being coated with sealing-wax, and connected with what is called a galvanic battery, be placed in this water, and if a small quantity of oil of vitriol be added to it, then bubbles will be seen to rise from the platinum ends of these wires. If two glass tubes of equal size be filled with water, and placed, as shown in Fig. 4, over the ends of the wires, bubbles

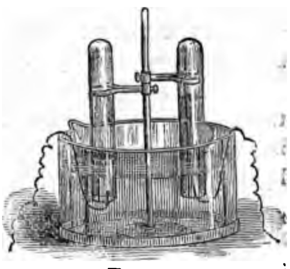

FIG. 4.

will rise through the water in the tubes and force it down. It will be noticed that one tube will fill more rapidly than the other, so that, when it is full, the other will be no more than half full. If

we now examine the two gases separately we shall find that they are very different. The gas which fills the tube will, on applying a light to the mouth of the tube, burn; the other gas will not burn, but, if a lighted match be put into it, the match will burn very brilliantly indeed. The first of these gases is called hydrogen, and the second oxygen. You will learn by these experiments that pure water can be separated into the two substances which compose it, and you also learn that one of these substances occupies a much larger space than the other—in fact, it measures just twice as much. Now, suppose these quantities of the two gases were to be weighed, the smaller quantity would be found to weigh eight times as much as the larger quantity; and remember there is twice as much hydrogen as oxygen by measure, so that if we were to take *equal* measures of the two gases, the heavier would weigh sixteen times as much as the lighter.

Hydrogen.—Let us now consider the nature of the lighter gas (hydrogen). We have seen that it is much lighter than oxygen; it is, in fact, the lightest substance which is known of in nature.

Now, as hydrogen is the lightest substance in nature, suppose we want to compare the weight of any other gas with hydrogen, we can do so by taking an equal measure of hydrogen and the other gas whose weight we wish to compare with it; and when we have found out how much heavier the other gas is than hydrogen, then, if we say that the

hydrogen gas weighs 1, the other will weigh, as for instance in the case of oxygen, 16.

Hydrogen gas exists in nature combined with oxygen in water. It also exists in all substances which are called animal, also in all substances which are called vegetable.

Hydrogen is a simple substance, and is therefore an element, but it is nowhere found in its simple state in nature.

You may prove that hydrogen gas is very light—much lighter than air—by filling an india-rubber air-ball with it. Directly you release the ball it will go up.

Preparation of Hydrogen.—If you wish to make some hydrogen gas in order to perform this experiment, the best way to do so is to take some zinc. First, melt the zinc, and when it is melted pour it into cold water. It will then become granulated. Or you can employ strips of sheet zinc. Put this into a bottle similar to that shown in Fig. 5; then pour through the funnel B some water and some common oil of vitriol. You will notice that an effervescence takes place, somewhat similar to that which happens when a bottle of soda-water is opened. The effervescence is owing to the escape of

FIG. 5.

hydrogen gas. If to the tube A, which comes out from the bottle, you attach your empty india-rubber ball, and if you put your hand on the top of the funnel, the ball will gradually enlarge, and when it is full you can tie it with a piece of cotton or thread above the mouth of the tube, and detach it from the apparatus. Now the substances which you have put into the bottle will act upon one another. The zinc acts upon the oil of vitriol, and as the oil of vitriol contains hydrogen, the zinc sets the hydrogen free, and it escapes. The water dissolves the substance, which is formed by the zinc and what is left of the oil of vitriol, after the hydrogen has gone. If the water were not used, hydrogen gas would not be given off freely. In order that you may understand properly what takes place in this action, you must know the names of the substances of which oil of vitriol is composed. It contains hydrogen, sulphur, and oxygen. When the hydrogen gas goes away, the sulphur and oxygen unite with the zinc and form a substance which, when pure, is a white solid. The hydrogen, sulphur, and oxygen in oil of vitriol are always present in exactly the same proportions. There are in 98 parts by weight of it 2 parts of hydrogen, 32 of sulphur, and 64 of oxygen; and when the zinc causes the hydrogen to be set free, it takes its place and unites with the sulphur and the oxygen; and the same quantity of zinc always takes the place of a certain weight of hydrogen—that is, 65 parts by

weight of zinc take the place of 2 parts by weight of hydrogen.

Oil of Vitriol.

Hydrogen	Sulphur	Oxygen
2	32	64
Zinc		
65		

If you add together the weights of the zinc, sulphur, and oxygen you will get 161, the weight of the white solid left, which is called zinc sulphate.

Impurities of Hydrogen.—When hydrogen gas is made in this way it is not pure. It contains water vapour, and in order that you may understand how this is, I must call to your recollection certain facts with which you are acquainted. You know that on a cold day in winter the windows become covered on the inside with water. Now from what source can this water come but the air of the room? and yet you cannot see any water in the air. It looks just the same as if it contained no water vapour. The water vapour settles on the windows because the windows are colder than the air in the room, and when air is made cold the water vapour which it contains is deposited as water. This you will see very strikingly illustrated if you examine a glass containing ice. The glass is covered on the outside with water, and this water not coming from the ice must come from the condensed vapour in the air. Again, suppose you put a shallow vessel containing water in a room, after a time the water will all disappear. What has become of it? It

has evaporated, *i.e.*, it has become vapour, and as vapour it exists in the air of the room. All gases when they come in contact or meet with water take up water vapour, and as the hydrogen gas in our experiment was set free in a bottle containing water it will be moist. There are other impurities too in this gas which you must know about, and from which you must know how to free it. The oil of vitriol used in its preparation contains arsenic. This is always an impurity of hydrogen gas which is made from common oil of vitriol. There are other impurities also, one only of which it is necessary to mention—viz., sulphur.

Purification of Hydrogen.—In order to have pure hydrogen gas you must free it from these impurities, and this is done in the following way:—A bottle, as shown in Fig. 6, is filled with fragments of pumice-stone, and these are moistened with some oil of vitriol. The gas is allowed to pass through this vessel, and the oil of vitriol takes away the water vapour from it. If you wish to free the gas from arsenic and other impurities, it should be passed through a bottle like the last, only containing a solution of nitrate of silver instead of oil of vitriol. The drying bottle with oil of vitriol should be placed after

FIG. 6.

that containing the solution of nitrate of silver; for the hydrogen would get wet again if it passed through the nitrate-of-silver solution last.

Flame of Hydrogen.—If the pure hydrogen be now allowed to escape through a tube with a small hole in the end, and if a light be applied, the hydrogen will burn, and its flame will be of a very faint blue colour. Sometimes, however, in practice the flame is yellowish, but this is owing to the presence of a substance contained in the glass. The

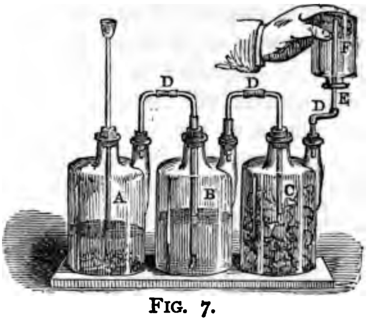

FIG. 7.

hydrogen flame gives no light, so that if it were burnt in a dark room you would not be able to read a book held close to it. You should remember this, because it will be of use to you when we come to speak on light-giving gases. Hydrogen is best collected by upward displacement, that is, by holding a bottle, F, with its mouth downwards, over the end of the delivery-tube, E (Fig. 7), which shows the complete arrangement of apparatus for making

pure dry hydrogen. A is the bottle in which the gas is set free; B contains the argentic nitrate;* C the pumice-stone and oil of vitriol; D, D, D are the places where the glass tubes are united by india-rubber tubing. Hydrogen gas can be obtained in other ways than this, and from other sources. There is a metal called sodium, the properties of which you will learn at some future time. One of them now, however, I will explain to you. If a small piece of sodium be thrown into water it will become round in shape, and you will see it travelling about the water in all directions. Its movements will be accompanied by a slight noise, and gradually the sodium will disappear, provided that it does not adhere to the sides of the vessel, in which case a flame will be produced. Now, if instead of sodium another metal called potassium be employed, as soon as it comes in contact with the water the piece will become round, but a very beautiful violet-coloured flame will be seen. In both these experiments the sodium or potassium acts upon the water, and breaks it up into the same gases which we saw that the galvanic battery broke it up into. The sodium and potassium take hold of all the gas called oxygen and unite with it, and half the hydrogen and unite with it also, but the remaining half of the hydrogen is set free. Where potassium is used the free hydrogen catches

* Argentic nitrate is the scientific name for nitrate of silver.

fire and burns, and this is the cause of the violet-coloured flame. In the case of sodium, however, we get no flame under ordinary circumstances, and it would be possible, by a properly contrived experiment, to collect the hydrogen gas, but it is a dangerous operation. What I wish you to remember is this, that in both these experiments only half of the hydrogen contained in the water is set at liberty; 23 parts by weight of sodium, or 39 of potassium, can take the place of one part by weight of the hydrogen of the water.

Hydrogen	Hydrogen	Oxygen
1	1	16
Sodium		
23		

Add the weights of the sodium, hydrogen, and oxygen together, and you get 40 parts of the compound, which is called sodic hydrate or caustic soda. It is when freed from water a white solid.

Oxygen.—Let us now consider how oxygen gas is made, and what are its properties. Oxygen gas is found in nature free in the air. You will understand this expression better when you have read about atmospheric air. You have also seen that it exists in water, and it also exists in what are called oxides: as an example of these, take iron rust. Oxygen gas was discovered by several great chemists at about the same time. The description of the method of its discovery had better be put off till a future period.

Preparation of Oxygen.—Oxygen gas is generally made from a substance called chlorate of potash, which is a compound, and contains three elements —chlorine, oxygen, and potassium—in the following proportions: $122\frac{1}{2}$ parts by weight of it contain $35\frac{1}{2}$ parts by weight of chlorine, 48 parts of oxygen, and 39 of potassium. This chlorate of potash is a white solid, not unlike crushed white sugar-candy.

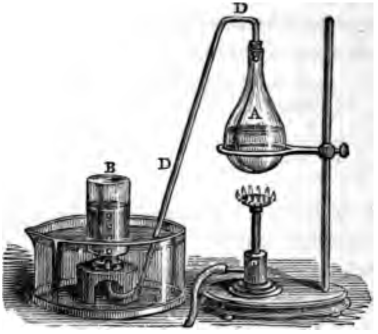

FIG. 8.

First of all this chlorate of potash should be heated gently in an open Berlin dish. It will then crackle, and care should be taken to prevent the pieces flying about, otherwise they will be lost. This can be done by putting a piece of paper loosely over the top of the dish. What is called a rose-burner should here be used, as there is less danger of cracking the dish. As soon as the chlorate begins

to melt it is better to remove it from the source of heat, and to allow it to get cool. It should then be taken out of the dish and broken up into small pieces, and put into a glass flask; a common Florence flask does very well, such as shown in Fig. 8. The flask must be carefully dried. A gentle heat should first be applied to the flask A, which may be increased gradually. The chlorate will melt, and will appear to boil gently. This apparent boiling is owing to the escape of oxygen gas. The oxygen gas will pass through the delivery-tube D D, and can be collected over water in the vessel B.

Certain Substances burn in Oxygen.—Some very interesting and instructive experiments can be performed with this gas. First, remove the vessel which has been filled with oxygen, placing your hand under the water on its mouth, so that the gas may not escape; when you have taken it from the water turn the mouth of the vessel upwards, then with your other hand light a thin piece of wood. Put out the flame, but allow the end of the match to glow. Then quickly remove your hand from the mouth of the bottle and insert this glowing match into the oxygen gas, and you will find that the flame will

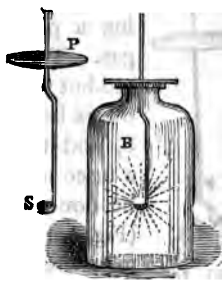

FIG. 9.

reappear, and the wood will burn with great brilliancy. If a larger vessel be filled with oxygen gas, such as is shown in Fig. 9, and be removed from the collecting trough in the same manner as the last bottle was, and if a piece of phosphorus previously lighted be put into it, the phosphorus will burn with intense brilliancy.* A similar experiment may be repeated, using sulphur instead of phosphorus. S is the spoon in which the phosphorus or sulphur should be placed. It should then be lighted with care, and placed gently in B, the bottle of oxygen; and the circular tin plate, P, should rest on the mouth of the bottle. There is, however, an experiment which is more difficult to perform, but which, when performed, is very beautiful and instructive. It consists in burning a piece of watch-spring in oxygen gas. The watch-spring must be made red-hot before being put into the gas; this is best done by fixing it to the spoon S, and then binding on to the spring a fusee made of tinder, which can easily be done with a piece of fine iron wire (Fig. 10). When the fusee is lighted it will make the spring red-hot, and in this condition it should be plunged into the oxygen. Now these experiments all show that oxygen

FIG. 10.

* Great care should be used in handling the phosphorus, as it may catch fire if rubbed; it should be carefully dried by gently pressing it between pieces of filter paper.

unites very readily with the substances employed, and when it does unite with them it forms compounds in which the substance used is chemically united with the oxygen. In the first two experiments a little water should be poured into the bottle after the burning, and the hand being placed on the mouth of the bottle, it should be shaken for a short time; after that a piece of blue litmus paper should be put into the water, and it will be turned red; this shows that new substances have been formed by the phosphorus and the sulphur with the oxygen, which have acid properties. (Acid properties will be explained in a later chapter.) In the third experiment the iron unites with the oxygen, forming what is called oxide of iron, which does not dissolve in water, and which has not acid properties.

When chlorate of potash is heated carefully it gives off all its oxygen, and the chlorine and the potassium, in the proportions before stated, are left behind united together, forming a substance called chloride of potassium. Remember that all the oxygen, forty-eight parts by weight, is set free. Sometimes, when large quantities of oxygen are required, black oxide of manganese is used. The method of making oxygen from this substance is different from that employed when chlorate of potash is used. As the black oxide of manganese must be heated very much more than the chlorate of potash, a vessel which will stand the high

temperature is required. An old gun-barrel, or better, a piece of iron gas-pipe, A, stopped at one end with iron, is very convenient for the purpose. The apparatus is made as shown in Fig. 11. C is a cork, D the delivery-tube. It requires a white heat to set oxygen free from black oxide of manganese, and even then all the oxygen cannot be obtained from it in a free state. The quantity which can be got is one-third of the oxygen contained in the black oxide of manganese used.

I have now described the methods of preparing

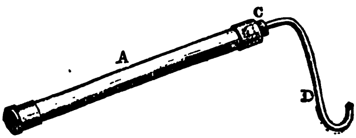

FIG. 11.

oxygen and hydrogen gases. Suppose you were to take one measure of oxygen and two measures of hydrogen, and put them together in a strong glass bottle, and if you were to apply a light to the mouth of the bottle, a loud explosion would take place. The two gases would unite, and water would be formed.

It has already been mentioned that when a light is put to the hydrogen gas coming out of a small hole in the end of a tube connected with the hydrogen apparatus, that the gas burns with a peculiar flame. If a perfectly dry glass vessel be held over this flame it will be covered internally with

moisture in a very short space of time. Now this moisture is water formed by the union of the hydrogen with the oxygen gas which exists in the air; and because there is hydrogen gas in coal, and because there is hydrogen gas in the common coal-gas we burn, and because there is hydrogen in candles and in the various oils which are burnt in lamps, when any of these substances burn in the air water is formed. I shall again speak of this subject more fully in another chapter.

CHAPTER III.

THE COMPOSITION OF CHALK.

CHALK is a white solid substance which easily marks upon dark surfaces; that shows it is soft. White marble is hard, and will take a fine polish, which chalk will not. If you examine carefully these two materials, you will find that the marble has small sparkling pieces in it. Now both these substances are chemically the same, but the particles of which they are composed are differently arranged, so that in the one we have softness, and in the other hardness and a brilliant shining appearance. There are also other substances which have the same composition as these two, such, for instance, as limestone, which is usually of a dark grey colour, sometimes even black; but when limestone is heated to a moderate

temperature it becomes white, and therefore that which gave it the black colour is in some way or other destroyed. Different coloured marbles owe their appearance to the presence of certain substances which it is not necessary for us to consider now, but they are all in the main of the same chemical composition as chalk. If a piece of chalk or marble of any colour, or limestone, be put into a bottle, and if a liquid, commonly called muriatic acid, but by chemists hydric chloride, be poured upon it, an effervescence will take place, and the chalk or marble, if sufficient acid be used, will in time be dissolved. If, however, marble or chalk be put into water no effervescence takes place, neither is the chalk or the marble dissolved. We see then that chalk is not soluble in water, but is soluble in this muriatic acid. It is also soluble in other acids, such, for instance, as vinegar, and when acted upon by vinegar the same sort of effervescence takes place.

Preparation of Carbonic Acid.—Now, if the bottle in which the marble is acted upon by the acid liquid be corked up, and a tube be inserted in the cork so tightly that nothing can escape but through the tube, and if the end of the tube* be placed under water, and then if a vessel full of water be inverted with its mouth downwards over the end of the tube, bubbles of gas will come from the bottle,

* The same apparatus can be used here as that shown in Fig. 12.

and will displace the water from the receiving bottle, which will become filled with gas. If now this bottle be carefully removed by the same method as was recommended in the experiment with oxygen, and if a lighted match be put into the bottle, the light will be immediately extinguished. If any small animal be put into the bottle it will soon cease to live. We have here then a gas different altogether from oxygen, and also different from hydrogen, because when a light was applied to the bottle containing hydrogen the hydrogen burned. But this gas will neither burn, nor will it allow other things to burn in it.

The usual way of collecting this gas is by what is called downward displacement. It will be seen presently that it is much heavier than atmospheric

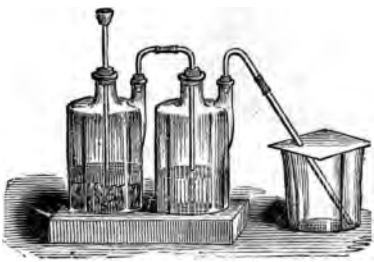

FIG. 12.

air, so that if the delivery-tube, instead of being placed under the water, be made to dip into an empty vessel, as shown in Fig. 12, the gas will

gradually pour into the vessel, and displace the air it contains, just as water does when it is poured into a glass. It is better to cover the vessel with a piece of paper while it is being filled; after that the paper can be carefully removed, and a lighted match can be inserted, which will be immediately extinguished. If then the vessel be carefully taken up in the right hand, the gas can be poured into another vessel held in the left (Fig. 13), and when the second vessel is full, the presence of the gas in it can be proved as before.

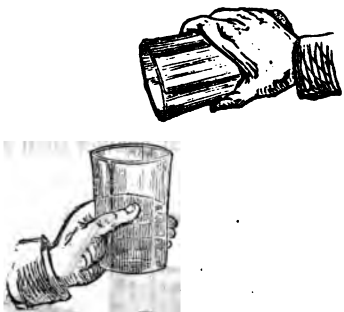

FIG. 13.

Let us consider from whence this gas comes. Not from the muriatic acid used, but from the lump of chalk or marble. The gas is called carbonic acid, and before it was set free by the acid liquid it was chemically combined with another substance, which is called lime. You will remember that when the method of making hydrogen was described it was

stated that zinc turned out hydrogen from oil of vitriol; here the acid liquid acts upon the chalk, and turns out carbonic acid from it. New substances are formed, which remain behind in the bottle. Now suppose the liquid which is left be put in an open dish and boiled, it will be found that when all the water has evaporated that a solid substance remains behind, and this solid substance is white, and in that respect resembles the chalk or marble from which it was obtained. I will now explain the changes which have taken place. We had chalk containing carbonic acid, and we had muriatic acid containing hydrogen gas united with chlorine. (The properties of chlorine will be described in their proper place.) Lime is a compound of a metal called calcium and oxygen. It is only necessary that you should remember this fact; it is not necessary at present that you should know about the properties of calcium.

Chalk or Marble.

Lime.

Chloride of Calcium.	Calcium. Chlorine.	Water.	Oxygen. Hydrogen.	Carbonic Acid.

Hydric Chloride or Muriatic Acid.

You will see from the way in which the substances are written down, that we have lime, composed of calcium and oxygen, and carbonic acid is written separately in the same line; the three sub-

stances form chalk and marble. Beneath the word calcium we have chlorine; beneath the word oxygen we have hydrogen, hydrogen and chlorine form hydric chloride, or, as we have hitherto called it, muriatic acid; the lines drawn in a vertical direction show you the new substances which are formed. Calcium and chlorine unite together, forming chloride of calcium; oxygen and hydrogen unite together, forming water; and carbonic acid is set free, and chloride of calcium is the substance which you get on driving off the water by heat. Chloride of calcium looks white like chalk, but it has this different property among others, that it dissolves readily in water.

Composition of Carbonic Acid Gas.—We will now consider the composition of carbonic acid gas. Carbonic acid gas is generally prepared in the way already described, but it is also formed in many other ways. Whenever wood or gas, or a candle, or coal, is burnt in air, carbonic acid gas is always produced, and you will presently know how you may prove this, and how you may detect its presence whenever it occurs. If marble, chalk, or limestone be heated to a high temperature, the carbonic acid is driven off, and lime is left. If either of these substances be broken into small pieces, and be put into what is called a hard glass tube and heated for some time, all the carbonic acid will be driven off, and the residue will not effervesce if, when it is cold, some acid liquid be poured upon it. There is a

substance familiar to us all which is called charcoal. It is black, and generally made from wood, although it may be obtained from other substances as well. If you put a piece of wood into a test-tube, and if you heat it, a quantity of smoke will issue from the end of the tube, and the wood will get red-hot, but it will *not* burn, because there is no air in the tube, it having been driven out by the heat. After a time condensed water will appear on the upper and cool part of the tube, also a brownish liquid, and if the heating action be continued long enough nothing will remain but black charcoal. Suppose now this piece of charcoal be taken out and placed in a tube which is open at both ends, and suppose the part of the tube where the charcoal is be heated gradually, you will perceive that the charcoal will become red-hot, and will glow and will disappear, little by little, till at last nothing will be left but a small quantity of a grey substance, so light that it may be easily blown away. Had you collected the gas formed by the burning of this charcoal, you would have found it to have the same properties as the carbonic acid obtained in the way before described. What happened in the tube was this:—The oxygen of the air came in contact with the red-hot charcoal, and the red-hot charcoal united with it, forming carbonic acid. We now see from this last experiment that carbonic acid contains charcoal, or, as we will in future call it, carbon; and you will

learn, when we have considered the composition of atmospheric air, that the other substance in carbonic acid is oxygen.

The other States in which Carbon exists.—Carbon is an element. It exists in three distinct forms: as charcoal, as a substance called black-lead, and as diamond.

Wood Charcoal.—Charcoal is made on a larger scale by heating wood out of contact with air in the following manner:—A shallow hole is dug in the ground, in which a fire is lighted, sticks of wood are placed across it and others across these again, so that a stack of wood is made. The whole is covered with sods of turf or some such substance, a hole being left at the bottom for the exit of air, and another on the opposite side, and at the bottom, for the entrance of air, which does not reach to the stack of wood. In this way the wood above the fire becomes heated and does not burn, but is converted into charcoal by a method exactly similar to that which was employed in the experiment performed with the test-tube.

Animal Charcoal.—Charcoal is also made from the bones of animals. If a bone be heated in a vessel, to which air cannot have access, but from which it may escape by a single opening, the bone will become perfectly black, and if it be examined its structure will be found almost unchanged. The animal matter of the bone has been driven away, and the carbon is left behind, together with some

other matters, which will in their proper place be described.

Properties of Wood Charcoal.—Wood charcoal appears to be very light, and if a piece of it be thrown on water it will float. This is because wood charcoal is full of a number of minute holes, and it therefore floats, just as an iron ship floats, because it contains air. If, however, the wood charcoal be broken into small pieces or into powder, and these little holes be destroyed, the powdered charcoal will sink in the water, showing that it is really heavier than water. Suppose some bad-smelling thing be placed in the bottom of a tall narrow vessel, and if charcoal be placed above it, so as to nearly fill the vessel, you will not, on putting your nose to its opening, be able to smell the bad odour. This is, perhaps, because charcoal being full of little holes is able to absorb bad-smelling gases. This property which charcoal has of absorbing gases, is very prettily shown by filling a test-tube over mercury with ammonia gas (Fig. 14), and putting in it a small piece of charcoal through the mercury, the mercury will begin to rise with tolerable rapidity, till at last the whole tube will become filled with mercury,

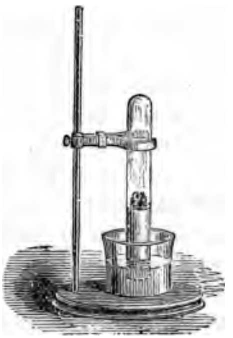

FIG. 14.

except where the charcoal is. In this case the charcoal absorbs the ammonia gas, and if you smell the charcoal you will detect a strong odour of ammonia. From its property of absorbing bad gases charcoal has been recommended as a substance to be placed at the openings of sewers, so as to absorb injurious vapours. Respirators are made of charcoal, and persons wearing them are able to enter rooms containing gases which would be injurious, or even fatal, to those who were not protected by them.

Black-lead, Plumbago, or Graphite.—Black-lead has scientific names: it is called graphite, and it is also known by the name of plumbago. It is used for the manufacture of lead-pencils, for polishing grates, and for making crucibles and vessels required to resist a very high temperature. It is found native in mines, where it occurs in large and small pieces, which pieces used to be carefully cut into strips and placed in cedar-wood: this form of plumbago makes the best kind of drawing-pencil. Powdered black-lead, when submitted to a heavy pressure, forms a hard mass, and lumps made in this way are now cut into strips for the manufacture of black-lead pencils. You will easily perceive how it is that other substances, such as small pieces of sand, may get with the black-lead, and those pieces of grit also which cause us so much inconvenience when we cut our pencil, and by scratching the paper when we write upon it. Black-lead is also compressed for household purposes, such as blacking grates, as well as for crucibles, etc.

Diamond.—The diamond is a very hard substance, and, as you know, is extremely brilliant. Its hardness is so great that with diamond powder other very hard precious stones can be ground and polished; this property of hardness makes it useful for cutting glass. It is generally supposed that all diamonds are colourless; this is not the case, for some are perfectly black. The diamond and black-lead and charcoal will all burn in oxygen gas, although the diamond and black-lead require to be heated to a very high temperature in order to enable them to do so, and all three, when burnt, form the same substance, carbonic acid.

Weight and Composition of Carbonic Acid.—When speaking of hydrogen we said that, because it is the lightest substance in nature, we compared the weight of all other gases with it, and we not only compare the weight of *gases* with it, but all other substances. If a measure of carbonic acid gas and an equal measure of hydrogen gas be taken, and if the two be weighed, it will be found that the carbonic acid weighs 22 times as much as the hydrogen. It is also known that the proportion in which carbon and oxygen exist in carbonic acid is as follows: 12 parts by weight of carbon and 32 parts by weight of oxygen; so that in 44 pounds of carbonic acid there are 12 pounds of carbon and 32 of oxygen; or in 44 grains of carbonic acid there are 12 grains of carbon and 32 of oxygen.

Decomposition of Carbonic Acid.—You will here notice, and the experiments already shown will have convinced you, that carbonic acid gas is formed by the union of a solid substance, carbon, with the gas oxygen, and solid carbon can be obtained from carbonic acid gas; for if you fill a Florence flask with carbonic acid by downward displacement, and, after removing the tube of your carbonic-acid apparatus, you place in the flask a small piece of the metal potassium, and then heat it over the flame of a lamp, all the time keeping your thumb on the mouth of the tube, or, perhaps better, keeping a cork *loosely* fitted to the mouth of the tube, you will see the potassium burst into flame after a short time, and when the flame has gone out you will find in the flask a deposit of black carbon. The heat should be applied to that part of the flask where the potassium is.

We have already seen that gases can hold water vapour and the vapour of certain liquids in suspension; water also is able to dissolve gases. A bottle of soda-water is a very good instance of this. If you look at a bottle of soda-water before the cork is loosened it will appear to be like a bottle of ordinary water, but if you loosen the cork the water will effervesce, and carbonic acid gas will be set free. Suppose soda-water be poured into a tumbler and be allowed to stand for some hours, it will become what is called "flat," and you will see no more carbonic acid given off; but if you put the soda-water into a kflas with a tube arranged as a delivery-tube, and if

you warm the flask, a very considerable quantity of carbonic acid gas will be driven off. Carbonic acid then is soluble in water. It is necessary that you should understand and remember this, as we shall have to speak of it again when we consider the impurities to which water is liable.

Test for Carbonic Acid.—I will now tell you the test by which you may discover the presence of carbonic acid. If lime be shaken up with distilled water, and kept for a short time in a stoppered bottle, a small quantity of the lime will dissolve in the water, and then if the clear liquid be poured off and kept in another stoppered bottle it will always be ready for use, but the bottle must be kept stoppered. The reason of this you will learn when we speak of the composition of atmospheric air. Whenever carbonic acid gas is allowed to bubble into lime-water the carbonic acid unites with the lime, and forms a substance of the same chemical composition as chalk; and you remember we found that chalk does not dissolve in water, and this substance when formed will not dissolve in water, therefore it causes the liquid to be milky, for it is white. The smallest quantity of carbonic acid may be detected in this way.

Carbonic Oxide.—You have perhaps, on a clear winter's night, when the weather is frosty, noticed that a pale blue flame flickers over the fire when all the black coal has disappeared. Now this pale blue flame is caused by the burning of a gas which is called carbonic oxide. Carbonic oxide, like

carbonic acid, contains oxygen and carbon, only that there is less oxygen in it in proportion to carbon than in carbonic acid. In any measure of carbonic acid gas there is just the same measure of oxygen as of the carbonic acid, that is to say, a quart of carbonic acid contains a quart of oxygen; but a quart of carbonic oxide contains only half a quart or one pint of oxygen. The composition of carbonic acid by weight is 12 parts of carbon and 32 of oxygen; the composition of carbonic oxide by weight is 12 parts of carbon and 16 parts of oxygen; therefore, if equal measures of these two gases be taken, the carbonic acid will weigh 44 and the carbonic oxide 28; but if equal measures of hydrogen and carbonic oxide be taken, the hydrogen will weigh 1 and the carbonic oxide 14. Now inasmuch as carbonic oxide contains more carbon in proportion to oxygen than carbonic acid does, if carbonic acid be passed through a tube containing charcoal heated to redness, carbonic oxide will be formed, and the volume of the carbonic acid will be doubled when it becomes carbonic oxide, that is, one litre* of car-

* A litre is a French measure, and is equal to 1·76 pints, that is, to a little more than one pint and a half. As French weights and measures are used in all modern scientific books, I shall, in future, use them exclusively in this work. The student will find no difficulty arise from this; for it matters not what we call the weight or measure of any substance taken, as the relation between it and any other

bonic acid will become two litres of carbonic oxide. Carbonic acid does not burn, but if a light be applied to the tube from which carbonic oxide issues it will be found to burn with a pale blue flame. Carbonic oxide does not turn lime-water milky. It is a very poisonous gas, much more so than carbonic acid, and it is this gas which has caused the death of many persons who have incautiously fallen asleep upon brick-kilns. A further description of carbonic oxide must be deferred to a future chapter.

CHAPTER IV.

ATMOSPHERIC AIR.

Composition of Air.—The atmosphere which surrounds the earth extends to a considerable distance above its surface; it is about 44 miles. It is well known that without atmospheric air no animal ould live, and the substance contained in atmospheric air which supports life is oxygen gas. You

measure will always be the same: for example, one litre of carbonic acid when converted into carbonic oxide becomes two litres, or one quart becomes two quarts. For the rules for converting the French weights and measures into ours, see "Cassell's Elementary Arithmetic," Part III. Every student of science, and, in fact, every person, should study the French decimal system of weights, measures of capacity, length and superficies.

have already seen that substances burn in oxygen, when pure, most brilliantly, but inasmuch as it is not in a pure state in atmospheric air, their burning is moderated; and so we and all other animals breathe oxygen diluted by another gas, the name of which is nitrogen. Oxygen and nitrogen exist in atmospheric air in the following proportions: in round numbers, one part by measure of oxygen to four parts of nitrogen. Now these two substances are not chemically united in air. They can easily, by several processes, be separated from one another. The office of nitrogen appears to be to dilute the oxygen, for if an animal were to be placed in pure oxygen it would shortly die from the powerful action that this gas would have upon its system.

Besides oxygen and nitrogen there are other substances contained in air; for instance, if you go into a darkened room where the light is admitted only by a small hole in a shutter, you will see moving about in the ray of light which enters by the hole, numberless particles of dust. Hydrogen gas when generated in contact with water, we have seen, contains water vapour. Atmospheric air also, which is continually in contact with water, contains water vapour, but the quantity of water vapour in atmospheric air is very variable. Air which did not contain water vapour could not be breathed with comfort. One experiences the inconvenience of this in a room heated by a closed stove. The way to remedy this is to have an open vessel con-

taining water placed in the room, so that the water may evaporate into the air and keep it moist. It is by no means difficult to prove the presence of moisture in atmospheric air. I have already alluded to a way by which it may be detected—viz., the condensation of water vapour on a cold window. The residue which we obtained in making carbonic acid from marble and muriatic acid, called chloride of calcium, is a substance often used to detect the presence of moisture. If chloride of calcium be made red-hot, so that it be quite dry, and if it be then placed when cold in the air it will soon absorb water, and in a short time will become dissolved. Oil of vitriol also, which I told you was employed for drying gases, gains weight when exposed in air by absorbing water vapour from it, so that if a small dish be partly filled with oil of vitriol and placed in one pan of a pair of scales, and if it be balanced by weights in the other pan, after a short time the pan containing the dish will be seen to outweigh the weights which at first balanced it, and this is owing to the absorption by the oil of vitriol of moisture from the atmosphere.

Carbonic Acid in Air: its uses.—As carbonic acid gas is formed by the burning of substances containing carbon, large quantities of it must be continually escaping into the air. Animals generally breath out carbonic acid gas, and this you can easily prove by blowing through a glass tube into a vessel containing lime-water, for in a few moments the lime-

water will become milky. There are other processes by which carbonic acid is set free into the air: carbonic acid therefore occurs in atmospheric air. At any given time there is not a very large quantity in the air; but inasmuch as carbonic acid gas is used up by plants, which require it for their support, and is being continually produced from the sources just mentioned, large quantities of it pass through the air. Animals breathe in oxygen, it is essential to the maintenance of their lives; and they breathe out carbonic acid. If there were not some means by which this carbonic acid was used up, it would accumulate in such quantities that animal life would become extinct. Almost all vegetables, however, require carbonic acid for their support: they take in this gas and keep its carbon and some of its oxygen, and set free the remaining oxygen, which escapes into the air, and of the carbon and oxygen retained their structure is in part made up, as well as products, such as sugar, starch, etc., which plants make, and which are very useful to us; and so the uniform composition of the atmosphere, as regards carbonic acid, is kept up. There is another substance in air, the properties of which we shall consider a little later, called ammonia. It does not exist there in large quantities, but still, like carbonic acid, it has an important office to play in the nutrition of plants.

That atmospheric air contains the various gases mentioned may be proved in several ways. Sup-

pose a test-tube containing atmospheric air be inverted over water with its mouth touching the water, and then if into this test-tube a piece of wire, to the end of which is attached a small piece of phosphorus, be put up, in the course of a short time the water will be seen to rise in the tube, and after the lapse of some hours the tube will be about one-fifth full of water, the remaining four-fifths will contain nitrogen. If the tube be stopped under water with the thumb, and be carefully removed, and its mouth turned upwards, and if the thumb be then taken away, and a piece of lighted wood be put into it, the light will be extinguished, for the oxygen, which alone of all the gases in air can cause substances to burn, has been absorbed by the phosphorus, just as it was in the experiment explained in the chapter on oxygen, when phosphorus was burnt in that gas, only the action is here slow, whereas in the former case it was rapid. This experiment shows one of the properties of nitrogen—viz., that bodies will not burn in it; and as bodies will not burn in it, animals cannot live in it.

Nitrogen Gas.—Nitrogen gas is usually obtained from atmospheric air by acting upon the air with some substance which will take away its oxygen: finely divided metallic copper is generally employed for this purpose. When air is passed through a tube in which this metallic copper is heated to a red-heat, it is deprived of its oxygen, and nitrogen passes on and can be collected. You already know

how to prove the presence of carbonic acid; if air be passed through lime-water the carbonic acid will unite with the lime, and the lime-water will turn milky. In order to obtain nitrogen in a pure state it is necessary to get rid of the solid particles which float about in the air, as well as the carbonic acid and water vapour, and this is done by passing the air first through a vessel containing cotton wool, and then through another containing something which will absorb the carbonic acid. Lime-water is not here used, but another substance which acts similarly to it, which is called caustic soda, and which has been alluded to already. It most effectually absorbs carbonic acid, which, however, does not produce in it the same milky appearance which it does in lime-water; and then if the air be passed through a bottle containing pumice-stone moistened with oil of vitriol, the water vapour will be absorbed by the oil of vitriol, and the nitrogen can be separated, in the manner already described, by passing it over heated metallic copper.

The weight of nitrogen as compared with hydrogen is this: a measure of nitrogen equal to a measure of hydrogen weighs 14 times as heavy as it does.

The apparatus used in the experiment just described is arranged in Fig. 15. A bottle, A, full of air is taken, to it is attached a bottle, C, containing caustic soda, and to this another bottle, D, containing lumps of pumice-stone moistened with oil of vitriol; to the tube leaving this bottle is attached

a larger tube of hard glass, E, and in this is put some finely divided metallic copper; F represents a row of gas-burners, and G is the receiver for the nitrogen. Water is poured very slowly through the funnel, and this forces out the air from A, and

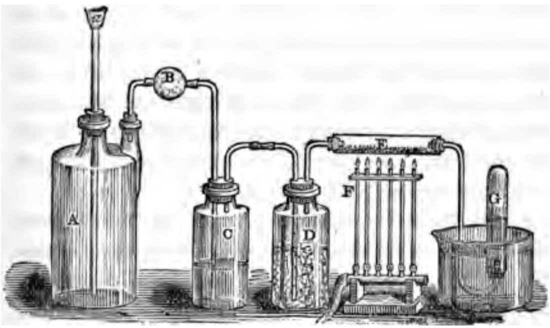

FIG. 15.

it passes through the bottles and tube, and in each loses one of its constituents. B is the bulb containing cotton wool.

It will be useful for you to know how it is proved that oxygen and nitrogen are not chemically combined in atmospheric air, and this is very simply done in two or three different ways. Suppose some air to be shaken up with water, the water will dissolve a portion of it. You have already been *told that,* when water is boiled, the gases dissolved

in it are driven off; if the water be boiled in this case after it has been shaken up in the air, and the air that was dissolved in it be driven off and collected, we shall find, on examining this air, that the oxygen and nitrogen do not exist in it in the same proportions in which they did before the air was dissolved in the water. There is about 1 part of oxygen to 4 of nitrogen in ordinary air, but in this air you will find that there are about 2 parts of nitrogen to 1 of oxygen, showing that the oxygen gas has been dissolved to a greater extent than the nitrogen. Now this could not take place if the oxygen and nitrogen were in chemical combination.

Again, there is a substance which is called pyrogallic acid; when this is mixed with caustic potash it forms pyrogallate of potash, and rapidly absorbs oxygen gas, when that oxygen is not combined chemically with any other substance. If some air be contained in a tube over mercury, and if some of this pyrogallic acid, which is a solid substance, be put into the tube through the mercury, and also some caustic potash or soda in the dry state, just as the charcoal is put up into the tube over mercury containing ammonia (as shown in Fig. 14), and then if a little water be forced up by means of a syringe, the pyrogallate of potash formed, which was before colourless, will be seen to change to a dark-brown colour, and gradually the mercury will rise in the tube until it occupies about one-fifth of the space *which was originally* filled with air.

Another proof is one, the full force of which you will not thoroughly understand at present, but it is well to allude to it in this place. There is a gas called nitric oxide, which is colourless and transparent. When, however, this gas comes in contact with free oxygen it unites with it and forms another gas, called nitrous acid, which is of a reddish-brown colour. When nitric oxide comes in contact with atmospheric air this brown gas is formed, and affords a proof that the oxygen of the air is free, and not in chemical combination with the nitrogen.

An experiment illustrating this can be performed by passing nitric oxide gas into a bottle, partly filled with air, standing over water. The method of making nitric oxide is explained in the chapter on the oxides of nitrogen (page 65). B is the bottle containing atmospheric air and water; D is the delivery-tube from the nitric oxide apparatus.

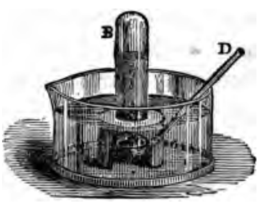

FIG. 16.

This illustrates the fact that nitric oxide and the oxygen of the air form nitrous oxide, which has a brown colour.

Before we leave the subject of atmospheric air, it will be necessary for you to know its weight with respect to hydrogen. We have seen that oxygen

weighs 16 times as much as hydrogen, and also that nitrogen weighs 14 times as much as hydrogen. In air there are about 4 measures of nitrogen to 1 of oxygen; if then we add 4×14 to 16, we shall get 72. We have then four equal measures of nitrogen and one of oxygen, making in all five measures, weighing 72, and if we take five measures of hydrogen, each equal to one of these, and compare them, we shall find that the five measures of air weigh about $14\frac{2}{5}$ times heavier than the five measures of hydrogen. Or if you divide 72, the weight of five measures of the mixed nitrogen and oxygen, by 5 you will get $14\frac{2}{5}$, which is the weight of one measure of the mixed gases, and as we take the weight of an equal measure of hydrogen to be 1, when the same measure of oxygen weighs 16, we say that atmospheric air is about $14\frac{2}{5}$ times as heavy as hydrogen.

CHAPTER V.

THE DIFFERENT KINDS OF WATER WHICH WE MEET WITH IN NATURE.

In the chapter where the chemical composition of water was described, it was mentioned that we meet in nature with different kinds of water—pump-water or spring-water, rain-water, river-water, and sea-water.

Spring-water.—The water which we obtain from springs has at one time or other been on the surface of the earth. Water from the sea is continually evaporating into the air, and this water is pure, for it leaves behind it all those substances which sea-water contains, and which make it so buoyant, and give it such a peculiar taste. The water vapour thus formed condenses, and comes down on the earth in the form of rain, and passes through the earth until it arrives at the spot from which it issues as a spring, or is raised by means of a pump. In its passage through the earth it dissolves substances, which will dissolve in water, with which it meets. An experiment will illustrate this. Put a small quantity of sand into a large funnel, and with the sand mix some salt or sugar, and pass water through this funnel; the water will be found to be either salt or sweet, according to which substance is used. The water has dissolved the salt or sugar in its passage. If you wish to get pure water from this mixture of salt and water, the best way to do it is to place the water in an apparatus similar to that shown in Fig. 2. The water, which is boiled in one vessel, passes through the tubes as steam into the other vessel, where it is condensed: the salt or sugar, or any similar substance, does not pass over with the water vapour or steam, but remains behind in the first vessel. Now all water containing such impurities as these—I mean *which are dissolved* in the water—can be purified

from them by this process, which is termed distillation. The evaporation of water from the sea, mentioned before, is a sort of distillation.

Water is raised from springs to the surface of the earth from various depths. There are surface wells, and there are deep wells called Artesian wells. The water from Artesian wells in certain localities contains lime in considerable quantities, and so also does the water in surface wells. The impurities in spring-water are generally called *mineral*, and vary, as you will easily understand, according to the substances which the water meets with in the earth in different neighbourhoods, and which it is able to dissolve. The point to be particularly remembered here is that they can be removed from the water by *distillation*.

Hard Water.—Lime in water is that impurity which renders it hard. Hard water is useless for washing purposes, and when a person washes his hands with soap in hard water the soap does not form a lather, but sticks to his hand, and appears to be greasy. It is the lime which produces this effect. You will remember that in a former chapter we spoke of lime as being soluble in water, and we said that if lime dissolved in water were exposed to carbonic acid a white substance would be formed, which is chemically the same as chalk, and which is insoluble in water. You will see from this that water which is exposed to air could not for *any length of time* contain in it lime in solution.

Lime usually exists in water in the form of carbonate, and this carbonate is dissolved by water containing carbonic acid gas in solution. You have already had explained to you how gases can be dissolved in water. You have also learnt that when water containing a gas in solution is boiled, that gas is driven off. Now suppose you take some water containing chalk dissolved in carbonic acid, and boil it, the carbonic acid which serves to dissolve the chalk will be driven off, and the chalk will be thrown down or precipitated. This will not be very apparent in ordinary drinking water, for the quantity of chalk in it is small, but you will very easily understand that this is the case if you examine a kettle that has been in use for some length of time. You will find it covered on the bottom with what is commonly called "furr"—*i.e.*, with a hard coating of earthy matter—and if you break up some of this coating and examine it, you will find that it is carbonate of lime. You will not be able to detect the lime; your knowledge does not extend far enough at present; but you will be able to detect the carbonic acid, for if you pour upon it a little muriatic acid (hydric chloride), carbonic acid will be given off, the presence of which you now know well how to detect.

Lime also exists in water in the form of sulphate; sulphate of lime is known by the common name of *gypsum*, or plaster of Paris, which is the product

formed when gypsum is made red-hot. This sulphate of lime is soluble to a certain extent in water, but it is not precipitated by boiling, as chalk is. The hardness which it imparts to water is called *permanent* hardness. Another very convenient way of correcting the hardness of water, when that hardness results from the presence of chalk dissolved in excess of carbonic acid, is by adding lime to the water; the lime added takes away the excess of carbonic acid and is itself converted into chalk, and allows the now insoluble chalk to be thrown down to the bottom of the vessel; and if some lime be dissolved up in the water purified from the chalk, if the water containing it be exposed for a short time to the atmosphere, that lime will become carbonate, through the carbonic acid in the air, and will be also thrown down. There are other impurities in spring water besides lime, such as potash, magnesia, and soda salts, and a substance called silica. All these impurities, which are usually called mineral, you will remember can be got rid of by distillation.

River-water.—River-water, in addition to mineral impurities, which, however it generally, contains in less quantity than spring-water, also has present in it impurities resulting from decaying animal and vegetable matter, and also from sewage and other similar contaminations. These most objectionable impurities can be got rid of by filtering the water *through any filtering* medium; the best, however, is

animal charcoal, which not only holds them back, but also decolourises the water, should its pure tint have been interfered with.

Rain-water.—Rain-water, which is the purest of all natural waters—for, as you have already heard, it has been distilled from the ocean—when collected with care, can be used in chemical experiments instead of distilled water. It, however, in passing through the air contracts a slight impurity, because it dissolves a gas which exists in small quantities, as you know, in air, and which is very soluble in water—viz., ammonia. It also dissolves some carbonic acid.

Sea-water.—Sea-water when evaporated leaves much more solid residue than spring-water, somewhere about $3\frac{1}{2}$ parts in 100 by weight, and this solid matter contains, as the taste of sea-water indicates, a large proportion of common salt. The bitter flavour of sea-water, which makes it so nauseous, is however due to the presence of salts of magnesia, sulphate, for instance, which we all know by experience to have a very unpleasant flavour, also chloride. Sea-water can be made pure by distillation, but then it has an unpleasant and insipid taste, as have all waters which have lost the gases dissolved in them by boiling, for it is owing to the presence of these gases that water has its brisk and pleasant flavour. When sea-water has been distilled, if it be passed through charcoal it will dissolve up some *of the air,* which you have already heard is readily

condensed in the small holes in the charcoal, and becoming aërated will recover its pleasant and agreeable flavour.

Test for Lime in Water.—Before concluding this chapter it will be well to tell you how you may detect the presence of lime in water, although it be there in but very small quantities. There is a substance called oxalate of ammonia, and if you add a solution of this to the water to be tested a white precipitate will be formed, if lime be present. But before adding the oxalate of ammonia it is better to put in a few drops of ammonia solution, because if the water were acid with a peculiar kind of acid a precipitate would not occur. Now if you add to the liquid containing the precipitate some acetic acid, as it is called, the acid contained in vinegar, the precipitate will not be dissolved.

CHAPTER VI.

COMBUSTION.

I HAVE up to this delayed speaking of what is called combustion, because I wanted you to have a knowledge of certain compounds before I spoke to you of what takes place when substances unite together chemically. You will remember, we have seen, that when a candle burns, as it is commonly called, water and carbonic acid are formed by the union of the hydrogen in the candle with the oxygen of the air, and the carbon in the candle with the oxygen in the air, and when a candle burns there is manifestly great heat produced and also light. Whenever substances unite together so as to form new substances, which are chemically different from the original substances, *heat is always produced*. It may not be sufficiently great for us to feel it, but an instrument called the thermometer will make us aware of its presence. If you put some quick-lime, as it is called, on a plate, and if you pour water upon it, the quick-lime and the water, both being cold, will when mixed produce a very considerable amount of heat, quite sufficient to cook

an egg: in this case the water unites with the lime, forming with it a chemical compound. Nor can the water be got away from the lime except it be heated to a high temperature. You will remember that when hydrogen gas is set free by the action of potassium upon water, sufficient heat is produced to cause some of the hydrogen to burn; now this heat is the result of the union of the potassium with the oxygen and half the hydrogen of the water. In the case of the burning of the candle, or of a gas-flame, or of a common fire, it is necessary that you should apply what is called a "light" to them, in order to make their constituents sufficiently hot to cause them to unite with the oxygen of the air, and then when they once commence forming this union they give out sufficient heat to keep up what is commonly called the "burning." In the experiment with lime no heat whatever was applied to the lime or water, and you saw that by their union they produced heat but not light; and in the experiment with potassium, cold potassium was thrown into cold water, and then sufficient heat was produced to set fire to the hydrogen gas which was set free.

This subject of combustion is very interesting, for the greater part of the heat required to keep our bodies in health is produced by a combustion which is going on continually in them; for the oxygen, of the air which we breathe, unites somewhere in our bodies with the carbon and hydrogen of the food which we eat, and forms carbonic acid and water,

producing heat, as truly as that which results from the union of the same substances which takes place when a candle or a fire burns. Always remember that no chemical union takes place without heat being produced.

It will be clear to you from what has been said that when substances are mixed together, and do not unite, they will remain chemically in the same state as they were when mixed, however finely their particles may be divided. If sugar and sand be rubbed together in a mortar you will not be able to distinguish the grains of sand from the particles of sugar, but no chemical union has taken place here, and this is therefore a mechanical mixture. The sugar can be separated from the sand by mechanical means, such, for instance, as washing it away with water, or by using a magnifying-glass and separating them particle by particle.

You will now doubtless be able to understand that there is no such thing as the destruction of matter, that burning only causes the matters which are burnt to change their combinations. It is said that when a candle or coal or any substance is burnt nothing is lost. A simple experiment will enable you to prove this. A (Fig. 17) is a glass tube which has been heated, drawn out at one end and bent, and the candle is placed under this, supported by a piece of wire gauze, so as to allow the air to pass in; C is a glass containing water, which is intended to keep the bent tube, B, cold, and in this

the steam formed by the combustion of the candle is condensed into water; D is another bent glass tube containing lumps (not solution) of caustic soda, which absorbs the carbonic acid. If the piece of candle be weighed before it is lighted, and if the two bent tubes be weighed before and after the burning, it will be found that the increased weight of both of them taken together is greater than that of the candle. If a candle be so arranged that all the carbonic acid and water formed by its burning be collected and weighed, it will be found that not only is nothing of the candle lost, but that the substances formed by its combustion are actually heavier than the portion of candle which has been burnt; and you will easily see the reason of this, for the carbon and hydrogen which were in the candle have united with the oxygen of the air to form these substances, and therefore their weight is increased by that of the oxygen with which they have united.

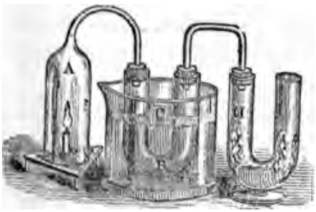

FIG. 17.

We will now consider the nature of flame. If you examine the flame of a common candle you will find that it is pointed. The shape of the flame *is owing to the fact* that its heat causes the air to *expand above it* in the direction A, and cold air

rushing in to take the place of the rarefied or lighter air in the directions B and C causes the flame to be pointed, as is shown in Figs. 18 and 19. On further examination the flame will be found to consist of three parts, two of which are very decidedly different from one another, but the third can only

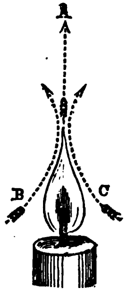

FIG. 18.

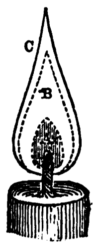

FIG. 19.

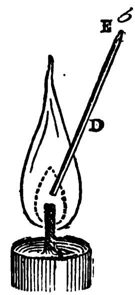

FIG. 20.

be seen on close observation. The centre part of the flame, A, nearest the wick is blue, and if a small glass tube, D, be placed in it, as shown in Fig. 20, the unburnt gases will pass through it and can be burnt by applying a light to its extremity, E. The next portion, B, is of a yellowish-white colour and gives light, and the outer coat, C, which is much thinner, gives little or no light. The blue part of the flame may be said to be the chamber in which the gases formed by the decomposition of *the tallow* of the candle are stored up; it is, in fact,

[illegible] The middle part of the flame [illegible] the light is given out, and the outer [illegible] more perfect combustion [illegible] the middle, and this part [illegible] little or no light.

If a piece of white porcelain be held in the flame it will be blackened by soot from the middle part of it, this soot [illegible] which has not mixed with the [illegible] of the air [illegible] because the air has not penetrated [illegible] the inner part of the flame; [illegible] made to pass into the [illegible] of a flame [illegible] escape unburnt. This [illegible] of the lamp which [illegible] a Bunsen lamp.

Fig. 41 shows this lamp partly in section. A is a tube through which gas mixed with air passes, the gas enters by the tube B, and escapes into C, which leads into A. There are four holes in C, one of which, D, is shown, and these open to the air and are placed in opposite sides of C; the air and gas then mix in C, and travel together up A, at the open end of which they are burnt. If a piece of white porcelain be held in this flame it will not be soiled, as no soot escapes; little or no light is given by it, but it is much hotter than a common gas flame.

Fig. 41.

Burning of a Fire.—In the grate we have a store of coal which contains carbon and hydrogen: when this coal is set on fire the air is drawn in by the draught at the bottom of the grate, A (Fig. 22), for the heat makes the upper air lighter, and cold air comes to take its place and passes through the fire. It is manifest that at the bottom of the fireplace the oxygen of the air is in excess of the carbon of the coal which is burning, and therefore carbonic acid gas is formed. This carbonic acid gas, passing through the hot carbon in the centre of the fire, B, becomes converted into carbonic oxide gas, and then when it comes to the upper part, C, it meets with excess of oxygen again, and burning with that oxygen becomes carbonic acid. The principle of this has been explained in the chapter on carbonic acid and carbonic oxide, where it was stated that carbonic acid passing over red-hot carbon takes up more of that substance, and becomes carbonic oxide.

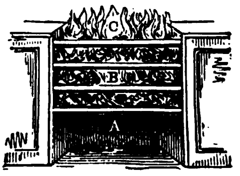

FIG. 22.

CHAPTER VII.

COAL.

Coal is a very complex substance, and there is very much difference in the composition of various kinds of coal. Some coals burn with a bright cheerful flame, others burn with little or no flame at all. The best flaming coal is what is called Boghead cannel coal, and the coal which burns with little or no flame at all is called anthracite. Coal is formed by changes which have taken place during long ages in forests of wood which have been buried in the earth. When coal is heated out of contact with air it is decomposed, and substances resembling those which we found to be given off when wood was heated, are produced. There is, however, one marked difference in them: ammonia is among the coal products, whereas an acid liquid is produced in quantities from wood, when heated out of contact with air.

Coal Gas.—The substances formed when coal is heated may be divided into gases, liquids, and solid residue. The gases formed are several; some of them burn, but give little light; one, however, pro-

duces a very luminous flame, and there are also present those which are considered as impurities in the gas produced. The names of the gases are these: hydrogen, marsh gas or fire-damp, olefiant gas, and carbonic oxide. These all assist in giving light, and they have mixed with them the vapour of certain liquids which are very luminous, such, for instance, as benzole, a well-known substance. The gases which are impurities are sulphuretted hydrogen and ammonia, and a small quantity of carbonic acid, and it is the work of the gas manufacturer to free his gas, as much as possible, from their presence. The liquids are, water containing ammonia dissolved in it (called ammoniacal liquor), coal-tar and liquids which contain hydrogen and carbon, and are therefore called hydrocarbons, and the solid residue left in the retort is coke.

Manufacture of Coal Gas.—Coal gas is made on the large scale by heating coal (Boghead cannel is the best) in long narrow fire-clay or iron retorts, the shape of which is shown in the accompanying section; they are much longer than they are wide or high. A movable end is supplied to the retort for filling it with coal, and for taking out the residual coke. When the charged retort is heated the gas passes off up iron tubes and bubbles through coal tar; the gas is cooled by passing it through long pipes, and here water and tar are deposited. It is then

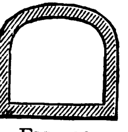

FIG. 23.

passed over lime, which arrests the carbonic acid and sulphuretted hydrogen, and sometimes over moist oxide of iron, for the purpose of further purifying it from sulphuretted hydrogen. The ammonia is taken away from the gas by dilute oil of vitriol, with which it, in its passage, is brought into contact. You can easily make coal gas on a small scale, by taking a test-tube and putting into it some coal broken into small pieces (of course a flaming coal should be used), and then closing the mouth of the test-tube with a cork, through which a piece of glass tube drawn out to a small point, and therefore having a small hole at its extremity, is passed. If the end of the test-tube containing the coal be heated, after a short time moisture will appear in the cool part of the tube, and smoke will issue from the hole, which will burn if a light be applied. In a little time the tube will be coated inside with a brown liquid, which is what is commonly known by the name of gas-tar. In performing this experiment the tube should be placed as represented in Fig. 24, otherwise the condensed water running back into the hot part of the tube will cause it to crack.

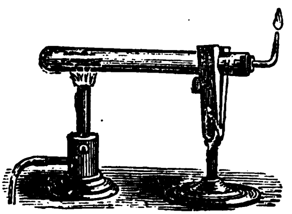

FIG. 24.

Marsh Gas.—In coal mines, marsh gas or fire-

damp (a name by which it is known in the coal pits), is continually escaping into the places where the miners are working. This marsh gas contains carbon and hydrogen in the proportions of 12 parts by weight of carbon to 4 parts by weight of hydrogen. When this is mixed with 10 times its measure of atmospheric air it will explode violently if it come in contact with a light; and it is to the presence of this gas that those serious explosions which too frequently occur in coal mines are owing. As marsh gas contains carbon and hydrogen when it explodes—*i.e.*, unites with oxygen—water and carbonic acid are formed, and this carbonic acid is called by miners "choke damp." Safety-lamps are used as a protection against its dangerous effects.

Davy's Safety-lamp.—The construction of the safety-lamp is so interesting that it must be described here. It consists of a lamp, the flame of which is entirely shut off from the air by a wire gauze covering; this wire gauze is made of extremely fine wires very closely woven together (Fig. 25). The principle upon which this lamp acts can be illustrated by the following experiment:—Take a piece of fine wire gauze, and put it over a gas-burner from which the gas is escaping, and then apply a light above the wire gauze; the gas which passes through

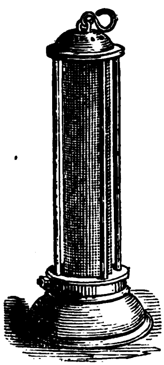

FIG. 25.

it will burn above the gauze, but you will perceive that there is no flame beneath the gauze (Fig. 26).

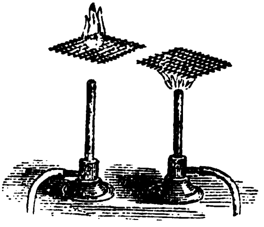

FIG. 26.

Now take the gauze wire and allow it to get cold, and light the gas. Place the gauze over the top of the flame, and you can bring it down to the opening from which the gas escapes; the flame will not pass through it, but the gas will burn beneath it. Metals are what are called good conductors of heat, and here the metal iron takes away the heat, so that there is not sufficient heat in the first experiment to ignite the gas below the wire gauze, nor in the second to ignite it above it. If, however, you break a few of the wires by making a few small holes in the gauze, and then try the experiment, you will find that the gas will burn above it and below it at the same time quite readily; and it is when, by some accident or carelessness of the workmen or by rusting, some of the wires in their lamp-guard break, that the heat is not properly conducted away, and the gas outside gets ignited.

CHAPTER VIII.

OXIDES AND NITROGEN.

We will now proceed to consider one or two of the compounds which oxygen forms with nitrogen. Oxygen does not unite readily and directly with nitrogen, that is to say, if you mix nitrogen and oxygen gas in a vessel, and try to cause them to unite, you will not succeed in doing so by applying a light or by any such means. The substances formed by them result from what is termed an indirect union of these gases. The oxides of nitrogen are five in number, but we shall only consider two of them.

Laughing-Gas or Nitrous Oxide.—The first, nitrous oxide or laughing-gas, very much resembles oxygen in some of its properties; substances will burn in it almost as brilliantly as in oxygen; it will also rekindle the embers of a glowing splint. It is a colourless transparent gas. This gas is interesting from the effect it produces on the human frame: when breathed, mixed with air, it causes considerable excitement, and hence its name, laughing-gas; but when breathed in the pure state it renders us insensible to pain, and, on account of this property, is used

by dentists and surgeons when they perform painful operations.

Composition of Nitrous Oxide.—Two measures of nitrous oxide contain oxygen and nitrogen in the proportion of two measures of nitrogen to one measure of oxygen by volume, and therefore by weight of 2 (14) or 28 parts by weight of nitrogen and 16 of oxygen; for a measure of nitrogen compared with an equal measure of hydrogen weighs 14 times as much as it does, and an equal measure of oxygen weighs 16 times as much as the hydrogen; and as there are two measures of nitrogen and one of oxygen in nitrous oxide, you will readily see how to determine the proportion of these gases by weight, for two measures of nitrous oxide weigh 44 and two measures of hydrogen weigh 2, therefore a measure of nitrous oxide weighs 22 times as much as an equal measure of hydrogen. It is made by heating ammonic nitrate in an apparatus similar to that employed in the making of oxygen gas from potassic chlorate. Ammonic nitrate breaks up into water and nitrous oxide. Its composition, therefore, is that of nitrous oxide added to the constituents of water, or 2 parts by weight of hydrogen and 16 of oxygen. The substances, therefore, that compose it are nitrogen, oxygen, and hydrogen in these proportions: 2 (14) parts by weight of nitrogen, 4 parts by weight of hydrogen, and 3 (16) parts by weight of oxygen, and if you arrange these elements in the following manner you will see that water and nitrous oxide are

produced: nitrogen 2 (14) and oxygen 16, hydrogen 4 and oxygen 2 (16); and if you remember the composition of water, hydrogen 2 and oxygen, 16, you will see that oxygen and hydrogen exist in ammonic nitrate in the proportions in which they form water. In making this gas you must not collect it over cold water, for it dissolves in it very readily; you should employ either hot water or water in which a very large quantity of salt has been dissolved.

Nitrous oxide may be distinguished from oxygen by the action of potassic pyrogallate and by nitric oxide, the experiments being performed in a similar manner to those which have already been explained as proving that oxygen is free in atmospheric air, for it is only free oxygen which is absorbed by potassic pyrogallate, and which can change the composition and therefore the colour of nitric oxide.

Preparation of Nitric Oxide.—Nitric oxide is also a colourless and transparent gas, and can be made by mixing hydric nitrate, also called nitric acid, the composition of which will be explained presently, with copper. Nitrate of copper is formed, which causes the liquid in the bottle to be green; water also is produced. The apparatus here used may be similar to that employed in the preparation of hydrogen, only that in the second bottle, instead of using nitrate of silver, simple water should be placed. When the action commences there will appear in the first bottle red fumes, and

as these bubble through the water in the second bottle the red colour will disappear, and the gas when collected over water will be quite colourless. If, however, the receiving bottle be only partially filled with the gas, and atmospheric air be bubbled up into it, a red coloured gas will be produced, which is called nitrous acid. It is this nitric oxide which is used for detecting the presence of free oxygen.

Composition of Nitric Oxide.—Nitric oxide contains nitrogen and oxygen in the proportion by volume of one part of nitrogen to one of oxygen, or 14 parts by weight of nitrogen to 16 of oxygen; it weighs 15 times as heavy as hydrogen. Substances will not burn in it, nor will it burn.

Hydric Nitrate, also called Nitric Acid or Aquafortis—Hydric nitrate is a liquid, and is composed of hydrogen, nitrogen, and oxygen in the proportion of 1 volume of hydrogen, 1 of nitrogen, and 3 of oxygen; or by weight, 1 part of hydrogen, 14 of nitrogen, and 48 of oxygen. It is a powerful acid liquid, and when dropped on the skin destroys it, turning it yellow, and causing for a time a painful burning sensation; when dropped on black clothes it discharges the colour, leaving a yellow spot. From its power of imparting a yellow colour it is sometimes used for dyeing woollen goods.

It is prepared from saltpetre or potassic nitrate, which when acted upon by hydric sulphate, also called oil of vitriol, gives off hydric nitrate. The

apparatus used for the preparation of this substance is generally a retort, A, with a receiver, B, as shown in the accompanying diagram (Fig. 27); a piece of paper, D, is put over the neck of the retort, and this is kept continually moistened with water in order that the acid may be condensed from the gaseous state, in which it passes over, into a

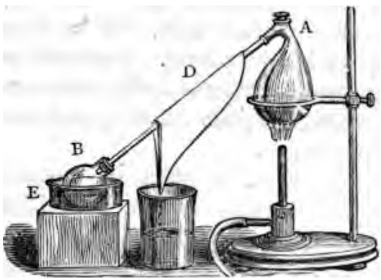

FIG. 27.

liquid. The receiver B ought also to be kept in a vessel, E, partly filled with cold water. Gentle heat is applied to the retort, so that the action may continue until the decomposition of all the substances employed s completed. Hydric nitrate remains as a yellow coloured liquid, which fumes when exposed to the air. The yellow colour is owing to its dissolving some of those yellow gases which you will see will fill the retort almost immediately after the action begins. One of the gases you have already heard about: it is called nitrous acid. Hydric nitrate contains other impurities

besides these; for instance, some potassic nitrate and hydric sulphate may pass over in small particles, and these running down the neck of the retort will get into the acid; therefore potassic nitrate and hydric sulphate may be impurities in hydric nitrate if it be not very carefully prepared.

Saltpetre often contains as an impurity some potassic chloride, and so hydric chloride, or as it is also called muriatic acid, will be found as an impurity of hydric nitrate. You will remember then that the impurities of hydric nitrate are potash, hydric sulphate, hydric chloride, and some of the oxides of nitrogen.

The proportions in which the potassic nitrate and hydric sulphate should be mixed are as follows, 101 parts of potassic nitrate and 98 parts of hydric sulphate, and these when completely decomposed will give 63 parts by weight of hydric nitrate. In order to purify the nitrate from the other oxides of nitrogen, which give it the yellow colour, it should be diluted with water; immediately this is done the yellow colour will be observed to disappear, and then if the mixture be distilled colourless hydric nitrate will be obtained, only it will not be as strong as it was when first made.

Hydric nitrate is very useful to the chemist; it is what is called an oxidising agent, that is to say, it is very easily decomposed, and gives up oxygen to substances which are capable of taking it. You will remember, that when nitric oxide

was made, copper decomposed the hydric nitrate and took oxygen from it, and oxide of copper was formed, and then an oxide of nitrogen, containing less oxygen than hydric nitrate, viz., nitric oxide, passed over, and the oxide of copper was dissolved by some hydric nitrate, and a green-coloured solution (nitrate of copper) remained in the generating bottle. When the whole of the hydric nitrate has been driven off from the mixture placed in the retort, a solid substance will be left behind, and this solid substance is called hydro-potassic sulphate. 101 parts of potassic nitrate contain—

101 parts of Potassic Nitrate.

136 parts of Hydro-potassic Sulphate.	Potassium (39).		Nitrogen (14).	Oxygen (48).	63 parts of Hydric Nitrate
	Hydrogen (1).	Sulphur (32).	Oxygen (64).	Hydrogen (1).	

98 parts of Hydric-Sulphate.

If instead of 101 parts 202 of potassic nitrate be employed, the decomposition will be somewhat different, for then we shall have—

202 parts of Potassic Nitrate.

174 parts of Potassic Sulphate.	Potassium 2 (39).	Nitrogen 2 (14).	Oxygen 2 (48).	126 parts of Hydric Nitrate.
	Sulphur (32).	Oxygen (64).	Hydrogen (2).	

98 parts of Hydric Sulphate.

the solid residue being called potassic sulphate, as it contains no hydrogen, and double the quantity of hydric nitrate will be obtained. The first of these two actions takes place at a moderate temperature, such as a glass retort will bear, but the second requires a very high temperature, and can only be performed in strong and suitable vessels. It will be well carefully to study the diagrams representing these decompositions, as a knowledge of the proportions in which different substances act on one another is *essential* to a sound and useful knowledge of Chemistry.

CHAPTER IX.

AMMONIA.

NITROGEN combines with hydrogen to form ammonia. The union, however, is not direct, that is to say, hydrogen and nitrogen when mixed together as gases cannot, by the application of heat, be made to unite.

Ammonia occurs in nature in the atmosphere, and is formed by the decomposition of animal and vegetable substances, which contain nitrogen and hydrogen. Animal jelly, bones, white of egg, and almost all animal substances, except fats,

contain nitrogen. There is also nitrogen in large quantities in vegetables; flour contains a substance called gluten, and this gluten contains nitrogen. Starch which exists in flour in combination with the gluten, and bodies like it, such as sugars, etc., do not contain nitrogen. When animal substances containing nitrogen are left exposed to the air they decay, and ammonia is given off. Ammonia was formerly obtained from hartshorn; this was done by a chemical process, but if the hartshorn decayed in the ordinary way it would give off ammonia.

Nitrogen and hydrogen exist in ammonia in the proportions of one volume of nitrogen and three of hydrogen, or by weight, of 14 parts of nitrogen, and 3 parts of hydrogen. If a measure of ammonia gas be weighed against a measure of hydrogen it will be found that the ammonia weighs $8\frac{1}{2}$ times as heavy as the hydrogen. Ammonia is easily distinguished by its very pungent odour; it is a colourless transparent gas and dissolves very easily in water, and its *solution in water* is what is used under the name of ammonia.

Ammonia can be prepared from a compound of ammonia with some of the acids, such as ammonic nitrate, from which you will remember nitrous oxide is made; the ordinary substance employed in its preparation is commonly known by the name of sal-ammoniac, called by chemists ammonic chloride. Now when this sal-ammoniac is mixed with lime, and gently heated, ammonia gas is given off.

56 parts of Lime.

111 parts of Calcic Chloride.					
	Calcium (40).	Oxygen (16).	18 parts of Water.	34 parts of Ammoni	
	Chlorine 2·(35½).	Hydrogen (2).		Hydrogen 2 (3).	Nitroge 2 (14)

Ammonic Chloride.

and as you doubtless remember lime is an oxide of calcium, the calcium unites with the chlorine of the ammonic chloride, part of the hydrogen of that substance unites with the oxygen of the lime, and the remaining hydrogen and nitrogen are set free as ammonia.

Ammonia gas will not burn readily. If, however, a stream of it be passed through the flame of a spirit-lamp it will continue to burn as long as it is in contact with this source of heat, nitrogen being set free and water being formed. Ammonia gas can be decomposed by the electric spark, and when it is decomposed the gases which compose it measure just double the volume of the ammonia gas taken, *i.e.*, if 1 litre of ammonia gas be decomposed 2 litres of the mixed gases will be produced, ¼ of which will be nitrogen and the other ¾ hydrogen.

The terms Acid and Base.—I have used an expression in this chapter which requires explanation: it is this, ammonia united with one or other of the acids. You will frequently hear the words *acid* and *base* used; I do not, however, intend to explain *fully* what an acid or a base is, but I will endeavour

o give you some notion of what is meant by these terms. Chemists use a substance called litmus paper, which may be either blue or red, according to the method of its preparation. When red litmus paper is brought in contact with a substance like ammonia or potash or soda, it turns blue; and when blue litmus paper is brought in contact with a substance which is called acid and tastes sour, it turns red. The former of these is said to be alkaline and the latter acid, or in common, though not very correct, language, the one is called an alkali, or a base, and the other is called an acid. If to an alkali, say ammonia in strong solution, an acid substance like hydric sulphate be added a violent action will take place, there will be a hissing noise as if melted metal were poured into water, and very great heat will be caused. I must here caution you not to perform this experiment with strong solutions, for it is very dangerous. The hydric sulphate should be diluted with a large quantity of water, and should be left to get cold, the ammonia solution should also be well diluted. If this addition be made with great caution, and if a piece of red litmus paper be from time to time dipped into the liquid, it will be found at last that the liquid will have no action in changing the colour of the red litmus paper; when you have arrived at this point the acid is said to have neutralised the alkali; if, however, you go beyond this point the acid will be in excess, and will cause blue litmus paper to turn red. Suppose the water

to be driven off by evaporation a solid substance will be left behind, and this solid substance, when carefully washed and cleaned, is what is called a neutral salt, that is to say, it has neither acid nor alkaline properties. There are acid salts and there are alkaline salts, and in these the acid or the base prevails. You have already had an instance of an acid salt formed in the preparation of hydric nitrate, viz., hydro-potassic sulphate.

CHAPTER X.

CHLORINE.

CHLORINE is a yellow-greenish coloured gas; it is transparent, and dissolves readily in water. Chlorine is never found free in nature: it could not exist free in nature for reasons which you will learn at some future period. Chlorine has a most offensive smell and a very powerful action upon the throat, eyes, and nose; it affects what are called the "mucous" membranes which line these organs. If breathed in large quantities chlorine acts as a violent poison. It exists in nature combined with other substances, and very largely in the form of common table-salt, which is chloride of sodium.

Chlorine gas is generally prepared from an acid

liquid called hydric chloride. When this substance, which contains hydrogen and chlorine, is acted upon by black oxide of manganese, heat being applied, chlorine gas is set free.

146 parts of Hydric Chloride.

126 parts of Manganous Chloride.	Chlorine 2 ($35\frac{1}{2}$).	Hydrogen (4).	36 parts of Water.	Chlorine, set free, 2 ($35\frac{1}{2}$).
	Manganese (55).	Oxygen 2 (16).		

87 parts of Black Oxide of Manganese.

A substance called manganous chloride is left in the retort, and water also is formed by the union of all the hydrogen of the hydric chloride with the oxygen of the black oxide of manganese, and half the chlorine of the hydric chloride is set free. If a volume of chlorine be weighed against an equal volume of hydrogen, the chlorine will be found to weigh $35\frac{1}{2}$ times as heavy as the hydrogen.

Compounds containing chlorine are used in the arts and manufactures. One of these is so important that I will describe its preparation; but, before doing so, I will call your attention to the changes which take place when chlorine gas is passed into water. Chlorine gas decomposes water; half of the hydrogen of the water unites with an equal volume of chlorine, the other half of the hydrogen and all the oxygen of the water decomposed unite with

a similar volume of chlorine, so that we get the following changes :—

18 parts Water.

Hydric Chloride, 36½ parts.	Hydrogen (1).	Hydrogen (1).	Oxygen (16).	52½ parts of Bleaching Liquid.
	Chlorine (35½).	Chlorine (35½).		

2 (35½) parts of Chlorine.

You will see that weights are taken here, but as you know what weight of chlorine occupies the same volume as a given weight of hydrogen, you will have no difficulty in understanding the diagram. If instead of water chlorine gas were passed over oxide of calcium or lime, you would see that the same sort of decomposition would take place :—

2 (56) parts of Lime.

111 parts of Calcic Chloride.	Calcium (40).	Calcium (40).	Oxygen 2 (16).	143 parts of Bleaching Powder.
	Chlorine 2 (35½).	Chlorine 2 (35½).		

4 (35½) parts of Chlorine.

In the place of hydrogen we have calcium, and the quantities of oxygen and chlorine are doubled. This last substance is called bleaching powder, commonly chloride of lime, and it is made in this way :—In a proper chamber, shelves of York flagstones are placed, fixed to the walls; these are

perforated with holes, and on them moistened lime is placed; chlorine gas is allowed to pass into the chamber, and in time the change indicated in our diagram takes place, chloride of calcium and bleaching powder being formed. In this operation the manufacturer is careful not to allow the temperature to rise too high, for, if it did, some of the bleaching powder would be lost, owing to the formation of another substance which is not useful as a bleaching agent. Bleaching powder destroys many vegetable colours, and when once they are destroyed by it they cannot be restored. Chlorine gas by itself when dry does not destroy vegetable colours, but when moisture is present it does do so, because in this case that substance which contains chlorine, oxygen, and hydrogen is formed, and it is this which bleaches, by giving up its oxygen to the colouring matter, and so destroying it.

Bleaching powder is commonly called chloride of lime; this is not a correct name for it. When it is used for bleaching, the goods to be bleached are dipped into a solution of it, and afterwards into an acid solution; this process is called "souring."

Chlorine does not combine directly with oxygen, *i.e.*, chlorine will not burn in oxygen, but other compounds of oxygen and chlorine besides that which is in bleaching powder exist. One of these you know something about already; it is contained in the substance called chlorate of potash. Chlorate of potash is made by passing chlorine gas into a

solution of caustic potash; a decomposition of the potash takes place, similar to that which takes place in water when acted upon by chlorine. Potassic chloride, and a compound containing potassium chlorine, and oxygen are formed. This compound is called potassic hypochlorite, and the one formed by the action of chlorine on water already described is called hydric hypochlorite, and that formed with calcium (bleaching powder) is called calcic hypochlorite. If potassic hypochlorite be boiled it is decomposed, potassic chloride and potassic chlorate, or chlorate of potash, being formed. The potassic chlorate is separated from the chloride by boiling the solution, and allowing the crystals of chlorate to form. I have not yet explained to you what a crystal is: this is perhaps the most convenient place to do so. If you dissolve some common salt in water and boil it, and then allow it to stand, solid particles will appear as the liquid cools, which have a peculiar form, and this form always belongs to common salt when it is deposited from its solution in water. Now these particles are called crystals. Again, if you boil some alum in water, and leave it to stand, youwill get crystals deposited, but these crystals will have a different shape from those of common salt. Sugar candy is crystallised sugar. If a syrup of sugar be made, and if it be boiled sufficiently, and if it be allowed to stand, when it gets cold crystals of sugar will be deposited. Different substances have different crystalline forms, although there are some sub-

stances which have the same crystalline form as others, but in such cases there is generally a similarity between them in chemical composition.

Hydric Chloride, called also Muriatic Acid and Hydrochloric Acid.—Chlorine unites with hydrogen directly. If a measure of chlorine be mixed with an equal measure of hydrogen, and if the mixture, in a glass bottle, be exposed to sunlight, an explosion will take place, the union of these two gases under such circumstances being so violent. If, however, the bottle be allowed to stand in a light room, to which direct sunlight has not access, a union between the two gases will take place slowly, and on examining the bottle after a time it will be found that all the chlorine and all the hydrogen have disappeared as such, and that in their place is an acid gas, which has a smell altogether different from chlorine, and which will redden blue litmus paper.

Composition of Hydric Chloride.—The volume of the hydric chloride formed is exactly the same as the volume of the hydrogen and chlorine taken together, so that in any measure of hydric chloride there is half its measure of chlorine and half its measure of hydrogen. This being the case, a measure of hydric chloride equal to a measure of hydrogen will weigh 18 times heavier than it, for the volume of hydrogen which composes the hydric chloride weighs 1, and the volume of chlorine weighs $35\frac{1}{2}$, together making 36, and compare this with a volume of hydrogen weighing 2,

and you will see that hydric chloride weighs 18 times as much as the hydrogen.

Hydric chloride is usually prepared in a manner somewhat similar to that which we employed in making hydric nitrate. Instead of potassic nitrate sodic chloride is taken, and this is acted upon by hydric sulphate. The sodic chloride should be

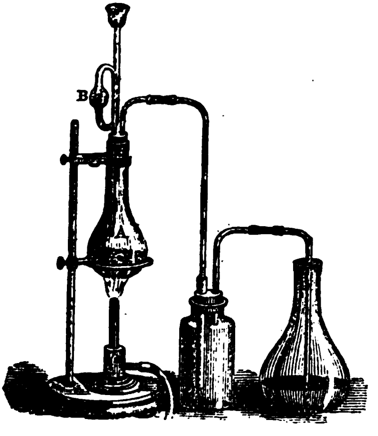

FIG. 28.

first heated to a white heat, in a crucible, until it melts; it should then be poured out upon a cold stone, and the solid mass broken up into pieces and put into a glass flask, A. The hydric sulphate should be added, and in this case what is called a safety funnel, B, should be used. The form of

the apparatus is illustrated in Fig. 28. Hydric chloride gas passes over through a wash-bottle containing a small quantity of water, and is dissolved in water contained in a receiver. The liquid usually used as hydric chloride is only a solution of the gas in water, and varies very considerably in strength. After the hydric chloride has been driven off there remains behind in the flask a solid substance called hydro-sodic sulphate.

58½ parts of Sodic Chloride.

120 parts of Hydro-sodic Sulphate.	Sodium (23).			Chlorine (35½).	36½ parts of Hydric Chloride.
	Hydrogen (1).	Sulphur (32).	Oxygen 4 (16).	Hydrogen (1).	

98 parts of Hydric Sulphate.

The impurities of hydric chloride are generally chlorine gas, which is dissolved in the hydric chloride solution; there may be some sodic chloride and also some hydric sulphate; arsenic, which you have already seen is an impurity of hydric sulphate, is always present in common hydric chloride; there is sometimes iron in it, which gives it a yellow colour, for when pure, hydric chloride solution is colourless.

Hydric chloride gas is colourless and transparent, it has a peculiar smell, and, as we have seen, is very soluble in water.

BROMINE.

Bromine is a substance which is classed in the same chemical family as chlorine, from its resemblance to it, and from its behaviour with other bodies. Bromine, which is a deep brown-red liquid, and extremely volatile, is obtained from sea-water. The method of its preparation is as follows :—Sea-water is boiled down to a very small bulk ; it is then allowed to stand, and crystals are formed in it when it cools ; the liquid is removed from these crystals, and is called the mother-liquid or bittern ; it contains bromine, which is chemically united with other substances, such as sodium or potassium. In order to free the bromine from these, chlorine gas is passed into this mother-liquid, and the bromine is set free, giving to the solution a yellow or brown colour, according as it is present in small or large quantities. The solution is then shaken up with ether, the ether dissolves the bromine, taking it away from the other liquid, and ether being lighter than water floats on the top. We have, therefore, a layer of ether containing bromine, and of a dark brown colour, floating upon a now colourless liquid. If the liquid, C, be allowed to drain away through a properly formed funnel, A, with a stop-cock, B (Fig. 29), the ether containing the bromine will be

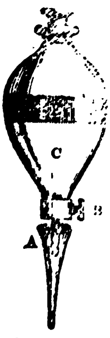

FIG. 29.

left alone on the stop-cock being closed, and it can be run off into a separate vessel. Ether and bromine both being volatile, they cannot be separated by distillation. Caustic soda is now added to the ether solution of bromine, the bromine unites with the soda, and the colour of the liquid is discharged; it becomes colourless. The mixture is then put into a retort and distilled, and the ether condensed and collected for further use. The residue is mixed with hydric sulphate and black oxide of manganese, and is then heated, the bromine is set free, and is condensed in a cooled receiver.

Properties of Bromine.—Bromine has a very pungent odour, somewhat resembling that of chlorine gas, only, if possible, more nauseous; when dropped on the skin it destroys it. The vapour of bromine is 80 times as heavy as hydrogen gas. Bromine united with potassium, forming potassic bromide, is now largely used in medicine. Hydrogen and bromine will not unite under the same conditions that hydrogen and chlorine will. When hydrogen and bromine vapour are heated to a high temperature they do unite, and a substance called hydric bromide is formed. You will perceive from this that chlorine unites more readily with hydrogen than bromine does, and is therefore said to have a greater affinity for it.

IODINE.

Iodine, another member of the chlorine family, is a dark metallic-looking solid. It is obtained from the ashes of sea-weed. If sea-weed be burned in the air, an ash will be left behind: if this ash be treated with water, a large portion of it will dissolve. If this solution be evaporated with a small quantity of hydric sulphate, substances which do not contain iodine will crystallise: if the liquid be then poured off from the crystals, and be still further evaporated and mixed with black oxide of manganese and hydric sulphate and heated, iodine will be given off as a beautiful violet-coloured vapour, and this vapour can be condensed in appropriate receivers.

The vapour of iodine is 127 times as heavy as hydrogen gas. Iodine dissolves in different substances, giving different coloured solutions. It dissolves very little in water, very readily in spirits of wine. In these cases the solution is brown, but when it is dissolved in a substance called bisulphide of carbon, it gives a very beautiful purple solution. Hydrogen and iodine cannot be made to unite together directly, and when hydric sulphate is mixed with sodic iodide iodine is set free, and hydric iodide is not formed as hydric chloride is, when hydric sulphate acts on sodic chloride, so that hydric iodide must be obtained by some other process. Chlorine, then, unites more readily with

hydrogen than bromine, and bromine more readily than iodine.

Potassic Iodide.—When iodine is mixed with a solution of caustic potash, it slowly dissolves: eventually the mixture becomes colourless: if, however, sufficient iodine be added to give the solution a permanent brownish tint, and if it then be boiled, compounds of iodine with potassium and iodine with oxygen and potassium will be formed: the compounds are called potassic iodate and potassic iodide. Potassic iodate like potassic chlorate contains oxygen. If after all the water has been driven off, the compounds be heated to a higher temperature, they will melt, and oxygen gas will be given off, just as it is when potassic chlorate is heated, and the residue will be simply potassic iodide. This is purified by crystallisation.

Test for Iodine.—Although I do not profess in this little book to give methods for testing, for the various substances described, yet the method of detecting iodine is so simple and so interesting that I cannot help describing it. Suppose you take a little potassic iodide in solution, and then if you put together in another test-tube some copper and hydric nitrate, nitric oxide will be, as you know, set free. This uniting with the oxygen of the air will form the red gas, nitrous acid. If you pour some of this nitrous acid—mind, the *gas*, not the liquid in the tube—into the test-tube containing the solution of iodine, and then if you shake the gas up with it, you will

immediately see that iodine is set free by the peculiar yellowish or brownish tint that is given to the liquid. Then if you pour a little starch into this, you will have a deep blue colour: this starch therefore indicates the presence of iodine infallibly. Reversing the action, you may prove in this way that starch exists in various vegetable substances; for if you set free iodine from potassic iodide, and then pour the liquid over a slice of potato, you will see that the potato will be blued, proving that starch is contained in it; or if you mix a little flour and water, and add the solution of free iodine to it, you will get a blue colour, showing that starch is one of the constituents of flour.

FLUORINE.

The beautiful substance, Derbyshire spar, or fluor-spar, contains an element which we shall now briefly consider, and which chemists have placed in the chlorine family. It is called fluorine. Now this element has rarely been obtained in the free state. It is never free in nature: we generally get it combined with hydrogen, forming hydric fluoride; from fluor-spar, in which it is united with calcium, forming calcic fluoride.

You remember that when hydric sulphate acts upon sodic chloride, hydric chloride is set free, and sodic sulphate is formed; but when hydric sulphate acts upon calcic fluoride, hydric fluoride is set free, and calcic sulphate is formed. The

preparation of this gas is somewhat difficult, and I should advise you not to try any experiment upon it, until you are well practised in chemical manipulations; for it is a very dangerous substance, injurious to the lungs, when breathed, and destructive to the fingers, when allowed to come in contact with them. As to its composition, it is made up of

78 parts of Fluor Spar.

136 parts of Calcic Sulphate.	Calcium, 40 parts.		Fluorine, 2 (19) parts.	40 parts of Hydric Fluoride.
	Sulphur, 32 parts.	Oxygen, 64 parts.	Hydrogen, 2 parts.	

98 parts of Hydric Sulphate.

equal volumes of hydrogen and fluorine, and is ten times heavier than hydrogen. The proportions in which they combine by weight are 19 parts of fluorine, and 1 part of hydrogen. Hydric fluoride, or as it is commonly called, fluoric acid, is used for etching upon glass, for it not only destroys glass, but will dissolve flint or sand. The way it is used in etching glass is as follows:—The glass is coated with wax, or some substance which resists the action of the hydric fluoride, a design or pattern is then scratched out of the wax, and the glass is submitted to the action of hydric fluoride dissolved in water. From its destructive action on glass it cannot be kept in glass bottles; gutta-percha or lead is generally employed.

CHAPTER XI.

SULPHUR.

BRIMSTONE is a yellow solid, and can be obtained from the shops in different forms. It is generally sold in short sticks, and is called roll-sulphur. It is also met with as a yellow powder containing little shiny crystals, and is then called, flowers of sulphur; in this form it is largely used in commerce.

There is, too, precipitated sulphur, the use of which is pretty much confined to medicinal purposes. Sulphur is found in nature in the pure state, in crystals of a peculiar form; they have eight sides; but it more generally exists in combination with metals in the form of what chemists call sulphides. Iron and sulphur united form iron pyrites, copper and sulphur, copper pyrites, which also contains iron; there is also lead sulphide which is called galena, and zinc sulphide which is called zinc blende. Iron pyrites is a very common substance, and it is often picked up in certain parts of the country on the sea-shore. It is used very largely as an ornament for mantelpieces. Sulphur is obtained from iron pyrites, by heating it in a closed vessel out of contact with air. The greater portion of the

sulphur is driven off by the heat, and is allowed to pass into another closed vessel, where it cools and forms into small crystals. This is the way in which flowers of sulphur are prepared.

If you hold in your hand a piece of roll-sulphur you will find it will crackle. Sulphur melts readily at a moderately low temperature, forming an amber-coloured liquid; if this liquid be poured into water, the sulphur will become solid, and the pieces will be as brittle as ordinary roll-sulphur. If, however the sulphur, instead of being poured into water, be heated to a higher temperature, you will find that it changes colour, it becomes dark and thick something like treacle, and if the heat be applied very carefully, it will be found in a short time that the mass of sulphur will become almost solid, so that if the vessel in which you have it be turned upside down it will not run down the sides. The further application of heat causes this solid mass to become liquid again; but the liquid now has a much darker colour than it had when it was first melted, and it flows about readily, but does not appear to be so liquid as it was when first melted. If now this liquid be poured into water, a strange change will manifest itself in the sulphur when it has cooled. Instead of being brittle it will be tough; it can easily be drawn out, like warm gutta-percha, into threads. It is soft, and the mass can be kneaded or pressed into moulds; but if it be left for about forty-eight hours, or perhaps a

little longer, it will lose this elasticity, and will become hard and brittle again. Great changes have been wrought in the sulphur by this prolonged action of heat: a further consideration of them would lead us too far in this work.

If sulphur be heated until it has melted the second time, and if then the heat be increased, the sulphur will be converted into a gas, having a reddish-brown colour. The most suitable vessel to perform this experiment in is an ordinary Florence flask: care must be taken, however, that the sulphur vapour does not mix with the atmospheric air, for if it do, the flask may explode. This may be prevented by keeping the flask regularly heated. If you put some copper or iron filings in a state of very fine division into the sulphur gas, they will immediately catch fire, and burn with a very beautiful flame. Let me now recall your attention to what took place when iron was put into oxygen gas. In this experiment the iron was heated first and then put into the gas, and it directly united with the gas, forming oxide of iron. In this last experiment the sulphur vapour is at a high temperature, and therefore it is not necessary to heat the iron filings before putting them into it; and here you see they unite with the sulphur, forming sulphide of iron. Other metals besides iron will unite with sulphur. Oxygen uniting with metals forms oxides, and sulphur uniting with metals forms sulphides. This will show you that there is a strong resemblance

between sulphur and oxygen, a resemblance which will be much more apparent to you, as you advance in your study of Chemistry. There, is, however, this difference between them: oxygen gas weighs 16 times as heavy as hydrogen, whereas a volume of sulphur gas when properly heated weighs 32 times as much as an equal volume of hydrogen.

Sulphurous Acid.—If in performing the last experiments with sulphur you happened to let the sulphur catch fire, it would burn with a blue flame, and you would get the smell of burning brimstone, the same as you have when a brimstone match is lighted. If, however, you do not let the sulphur catch fire when it is in the state of gas, you get from it little or no smell at all; so that the smell, when sulphur burns, is not owing to the sulphur, but to the burning of the sulphur with oxygen, for the sulphur does not burn unless it comes in contact with air or oxygen. When sulphur burns in air or oxygen, sulphurous acid gas is formed. It is colourless and transparent, having the peculiar smell above mentioned, and it is also very soluble in water. A measure of sulphurous acid gas weighs 32 times as much as an equal measure of hydrogen, and it is composed by weight of 32 parts of sulphur, and 32 parts of oxygen; and by volume, of one volume of sulphur vapour, and two volumes of oxygen gas; and these when chemically united in sulphurous acid gas form two volumes of it, each being equal to the volume of sulphur

vapour, or to one volume of its oxygen. Sulphurous acid has bleaching properties, but it does not bleach in the same way that chlorine does. It is said that the colour of substances bleached by sulphurous acid may be restored by a proper treatment. This cannot be done when the bleaching effect is owing to the action of chlorine.

Sulphurous acid is generally prepared in the laboratory by treating hydric sulphate with something which will decompose it, so as to set sulphurous acid free. Charcoal is generally employed for this purpose. If hydric sulphate be boiled with charcoal in a vessel similar to that used for the preparation of hydric chloride, sulphurous and carbonic acids and water will be formed. Sulphurous acid being soluble in water is generally collected in that substance, and this solution is kept for use in the laboratory. Care, however, must be taken to keep the bottle in which it is preserved well stoppered, for sulphurous acid in solution very readily takes up more oxygen, and forms hydric sulphate. This will be explained in the next chapter on the manufacture of oil of vitriol.

If sulphurous acid be added to a solution of caustic potash, and if the liquid be evaporated, a solid crystalline substance will be formed, which is called potassic sulphite. Remember this termination, "ite," as I shall refer to it again in the next chapter.

CHAPTER XII.

HYDRIC SULPHATE.

YOU were told in the last chapter that a solution of sulphurous acid takes up oxygen readily, forming hydric sulphate, whereas when sulphur is burnt in air or oxygen no other compound with oxygen is formed but sulphurous acid. We shall in this chapter consider the composition of hydric sulphate, and how it is made commercially. Hydric sulphate, commonly called oil of vitriol and sulphuric acid, has a composition which has already been explained to you. In it there are 32 parts by weight of sulphur, 2 of hydrogen, and 64 of oxygen.

If you take a small quantity of sulphurous acid in solution, and if you boil it with a drop or two of hydric nitrate, it will be oxidised, and hydric sulphate will be formed, hydric nitrate being, as you have already learned, a powerful oxidising agent. Suppose some nitric oxide gas be collected in a dry bottle, and be then passed into a bottle containing atmospheric air, the nitric oxide will be converted into nitrous acid, and its colour will become red;

then suppose some sulphurous acid, made by the action of charcoal upon hydric sulphate, be passed in, after a short time the red colour of the nitrous acid will disappear, and the sides of the vessel will be coated with a white solid substance. If some more air be passed into this vessel, the red colour will appear again, and if more sulphurous acid be made to enter it, that colour will disappear, and if this action be repeated for some time a large quantity of the white substance will be formed in the glass vessel. What has happened here is this:—Nitric oxide when it meets with air becomes nitrous acid; sulphurous acid takes away the oxygen which the nitric oxide took from the air to become nitrous acid, so then the sulphurous acid gets more oxygen, and the nitrous acid is deprived of it: this action keeps going on as long as the two gases are passed in, air being present. If now a little water be poured down the side of the glass flask containing this white solid, it will be noticed that a brisk action will take place. There will be a sort of effervescence, and considerable heat will be produced. When the whole of the white substance is dissolved in water it will have become hydric sulphate; for the sulphurous acid, which contains 32 parts by weight of sulphur and 32 parts by weight of oxygen, has taken up by means of the nitric oxide 16 parts by weight of oxygen more, and then by the addition of water it has taken up 2 parts of hydrogen by weight, and another 16 of

oxygen, and adding these together we shall find the proportions of the elements to be the same as we know them to be in hydric sulphate.

Manufacture of Commercial Hydric Sulphate or Oil of Vitriol.—Now hydric sulphate or oil of vitriol is made on the commercial scale in the following way:—A large leaden chamber is employed, the bottom of which is covered with water to a slight depth. Iron pyrites is heated in a furnace, through which air is allowed to pass; the sulphur, being set free at a high temperature in the presence of oxygen, becomes sulphurous acid, and this enters the chamber. In another vessel, sodic nitrate and hydric sulphate are put together; hydric nitrate is formed just the same as when potassic nitrate and hydric sulphate are employed. This hydric nitrate gets acted upon by the sulphurous acid in the leaden chamber, and nitric oxide is formed. Nitric oxide then takes up oxygen from the air which is in the chamber, forming nitrous acid, and the sulphurous acid immediately takes the oxygen from it. Jets of steam are being continually forced into the leaden chamber from a boiler of water, and this steam unites with the sulphurous acid, which has taken up more oxygen, and so hydric sulphate is formed; the hydric sulphate is dissolved by the water in the bottom of the leaden chamber, and this operation is carried on until the solution of hydric sulphate becomes sufficiently strong. At this point it is in an im-

pure state, and is known by the name of chamber acid. It can be made stronger by evaporation, and when this is done the operation is now performed in platinum vessels, for strong hydric sulphate has an action upon lead, lead sulphate being formed, which is dissolved in the strong hydric sulphate.

Impurities of Oil of Vitriol.—The presence of lead may be detected in a common specimen of this acid liquid, by diluting it with water, for if lead be present the mixture will become turbid, because lead sulphate is not soluble in dilute hydric sulphate or in water. Common hydric sulphate contains other impurities, such as arsenic, sulphurous acid, and hydric nitrate. When hydric sulphate is mixed with ammonia solution, or with a solution of caustic potash, or soda, and the water is evaporated off, the solid substance left is called a "sulphate." In the last chapter a similar process with sulphurous acid in solution was said to form a "sulphite." The termination "ate," when it is used for salts formed by certain acid substances, always means that there is more oxygen in the body than when the term "ite" is used, so that a "sulphate" contains more oxygen than a "sulphite," and a nitrate contains more oxygen than a "nitrite," and the termination of the name of the acid is either "ic" or "ous," according as that acid contains more or less oxygen, the "ic" indicating the presence of the larger quantity of that element, and the "ous" the

smaller quantity, as sulphuric acid, which contains more oxygen than sulphurous, and nitric acid, which contains more oxygen than nitrous acid.

Sulphuretted Hydrogen.—Sulphur forms a compound with hydrogen called sulphuretted hydrogen, which is a colourless, transparent gas, very soluble in water, and having an extremely unpleasant odour like the smell of rotten eggs, the presence of which is due in stale eggs to the formation of this gas, as eggs contain a considerable quantity of sulphur. Sulphuretted hydrogen is formed in drains and cesspools, and escapes into the air, tainting it with its bad odour, and is said to be extremely injurious to health. The substance whose composition we studied, when speaking about chlorine, called bleaching powder or chloride of lime, destroys the bad smell of sulphuretted hydrogen, as you doubtless are aware of; so also will chlorine gas when it is moist. The action takes place in this way:—Moist chlorine forms a compound of chlorine, oxygen, and hydrogen already spoken of, and the oxygen of this substance unites with the hydrogen of the sulphuretted hydrogen, forming water, and sulphur is set free.

Sulphuretted hydrogen consists of sulphur and hydrogen in the following proportions:—2 parts by weight of hydrogen and 32 of sulphur. You would not have much difficulty in determining the quantity of that chlorine compound containing

oxygen which must be taken to decompose a given weight of sulphuretted hydrogen, for the sulphuretted hydrogen contains 2 parts by weight of hydrogen, and therefore the chlorine compound must be of such a weight as to contain 16 of the same parts by weight of oxygen: for example, suppose 34 grammes* of sulphuretted hydrogen meet with $52\frac{1}{2}$ grammes of the chlorine compound, 18 grammes of water will be formed, and 32 of sulphur precipitated. A measure of sulphuretted hydrogen weighs 17 times as heavy as an equal measure of hydrogen gas.

The best way to obtain this gas is to act upon a sulphide with dilute hydric sulphate, and the sulphide usually employed is a sulphide of iron, which can be easily made by heating iròn and sulphur together. The action which takes place is the change of iron for hydrogen in the hydric sulphate, and the union of that hydrogen with the sulphur of the sulphide of iron.

88 parts of Sulphide of Iron.

152 parts of Sulphide of Iron.	Iron (56).	Sulphur (32).	34 parts of Sulphuretted Hydrogen.
	Oxygen 4 (16). Sulphur (32).	Hydrogen (2).	

98 parts of Hydric Sulphate.

Sulphuretted hydrogen is used by chemists in

* One gramme weighs a little less than $15\frac{1}{2}$ grains.

the laboratory for precipitating metals from solutions, and the precipitates formed are called sulphides. If sulphuretted hydrogen be passed into a solution of sugar of lead a black precipitate will be immediately formed, or if a substance known as the paint called white lead be brought in contact with sulphuretted hydrogen, it will turn brown, and eventually, if exposed long enough, will become black, owing to the formation of sulphide of lead. Sulphuretted hydrogen burns in air with a greyish flame which gives no light, sulphurous acid being formed by the oxygen of the air uniting with the sulphur of the sulphuretted hydrogen, and water, by the union of oxygen from the air with the hydrogen of the sulphuretted hydrogen.

CHAPTER XIII.

PHOSPHORUS.

THIS substance, so dangerous to handle on account of the serious burns which it can inflict, is never found free in nature. The source from which it is usually obtained is called bone-earth, and this bone-earth is the residue which is left behind when bones have been well burned in the fire. If you take, say, a mutton-bone, and put it in the centre

of a hot fire, the animal matter in it will be thoroughly burnt out. If the bone be not thoroughly burned, portions of it will be black, and these consist of animal charcoal; whenever this happens, all that is required is to burn the bone for a longer time, and then the carbon in it will unite with the oxygen of the air, and pass off as carbonic acid. The white residue after heating, provided the experiment has been very carefully performed, does not differ in shape from the bone originally taken, but if it be struck a smart blow it will break, showing that it is now brittle, whereas the bone formerly was tough, and this want of toughness is owing to the destruction of the animal matter of the bone: from a deficiency of animal matter in them the bones of old people are brittle. When this white substance is powdered it goes by the name of bone-earth, and contains a considerable quantity of phosphorus in combination with lime and oxygen. If this bone-earth be treated with dilute hydric sulphate, a portion of it will be dissolved out, but there will still be a solid substance left behind, and that solid substance is of the same composition as the plaster used for making images, and is called sulphate of lime. If the liquid be poured off it will contain the phosphorus together with lime, oxygen, and hydrogen, but there will be less lime in it than in the bone-earth. Such a liquid can be obtained by treating a fresh bone, that has not been burned, with dilute hydric sul-

phate; and it is interesting to remark here, that when the bone has been left sufficiently long in this acid liquid, it will become quite soft, so that you can easily cut it with a knife; it will still retain its toughness, but its hardness will be gone, for the earthy substance which gave it its hardness has been dissolved out by the acid liquid. In the bones of infants there is but a small quantity of mineral matter, therefore they are somewhat pliable. The shape of the bone in this case will remain the same as it was before treating it with the acid. Now either of these liquids can be taken for the preparation of phosphorus, though it is usual to employ the method first described. The liquid is evaporated until it becomes thick; it is then mixed with charcoal and heated in a suitable apparatus, and phosphorus distils over and is condensed in water. Sticks of phosphorus are round, and from four to six inches long. The phosphorus having been condensed in water is melted by warming the water, and is then purified, and allowed to run into moulds which are under the warm water, where it becomes solid on cooling. Phosphorus in this form looks almost like a stick of white wax, though it becomes yellowish in time; it is always kept in water, because if it were allowed to be exposed to the air, it would gradually disappear, for it would unite with the oxygen of the air, giving rise to white fumes, in which state it would pass away and be lost.

Phosphorus is luminous in the dark, and therefore it has been used for writing with on walls; this practice, however, should never be indulged in by boys who are not thoroughly acquainted with its properties, for if once the phosphorus catches fire, which it will easily do by the heat caused by rubbing it on the wall, it will inflict most serious wounds on the fingers, for it will continue to burn till it is all exhausted; for even if you plunge your hand in water it is only extinguished for a time, and on taking your hand out of water the phosphorus catches fire again.

Phosphorus is used in the manufacture of lucifer matches, and is a very violent poison. You should be careful, therefore, not to get any of the substance on the ends of lucifer matches in your mouths, for a very, very small quantity is sure to cause a painful death.

Red Phosphorus.—If a piece of phosphorus be put into a glass flask, and if carbonic acid be passed into it, so that no air be present, which means the same as saying that no free oxygen is present, and then if the flask be heated it will be found to be covered with a reddish-brown substance when cold, and this reddish-brown substance is phosphorus in another form, which is not nearly so active, chemically, as the waxy phosphorus, and can be handled with much greater safety, as it requires a greater amount of heat to ignite it than does the yellow or waxy phosphorus. This red phosphorus is now largely employed in the manufacture of

lucifer matches, because it causes much less injury to the workmen than the other kind, which, when it was used, affected the bones of their mouths, causing them to decay.

Phosphorus and Oxygen.—Phosphorus unites with oxygen; when it is burned in oxygen a white powder is formed (if no moisture be present), which is called phosphoric acid. Phosphoric acid has a powerful attraction for water, and is used instead of oil of vitriol or calcic chloride for drying substances. As a proof that its energy is greater in this respect than hydric sulphate, if it be heated with that body, it takes away from it the elements of water.

If a piece of phosphorus be boiled with a mixture of 1 part of hydric nitrate to 4 parts of water, until all the phosphorus has disappeared, a substance called hydric phosphate will be formed; red fumes will be given off during the whole of the operation, showing that the hydric nitrate is giving up some of its oxygen to phosphorus; while the rest of its oxygen and nitrogen unite, forming other oxides of nitrogen. This hydric phosphate is a very interesting substance, but the consideration of its composition must be left to a later period. When the dry phosphoric acid, formed by the burning of phosphorus in air or oxygen, is mixed with water, the same substance—hydric phosphate—is produced.

Phosphuretted Hydrogen.—If a lump of phosphorus be put into a glass retort, and if the retort

be quite filled with a solution of caustic soda, and then if the end of the retort be dipped into a little dish which also contains the same solution (the arrangement is given in Fig. 30), and then if heat be applied gently to the retort, the liquid will be gradually forced out, and the space above it will be occupied by a gas. At last the gas will issue in bubbles from the end of the neck of the retort, and these bubbles, on coming in contact with the air, will burst into flame, forming beautiful rings of

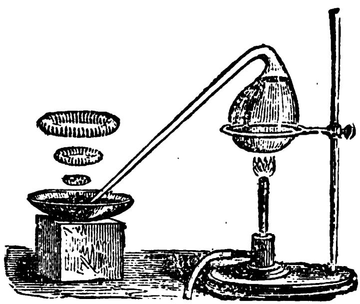

FIG. 30.

white smoke. This is a very pretty experiment, but should be performed with great care; no air whatever must be allowed to remain in the retort—it must be perfectly filled with solution of caustic soda, for if air be inside it, as soon as the gas is generated, an explosion will take place.

Now this gas is called phosphuretted hydrogen,

and contains 31 parts by weight of phosphorus and 3 parts by weight of hydrogen. A measure of it will weigh 17 times as much as an equal measure of hydrogen. Probably you will recollect that ammonia gas contains 14 parts by weight of nitrogen, and 3 of hydrogen; you see there is then a similarity between these two gases in their composition. When the phosphuretted hydrogen escapes into the air, the oxygen of the air unites so readily with the phosphorus that it burns, hence the flame, and the rings of white smoke formed are rings of phosphoric acid; the hydrogen of the phosphuretted hydrogen of course unites with the oxygen of the air to form water.

CHAPTER XIV.

SILICA.

Silica is the scientific name for the principal constituents of flint, sand, and rock crystal; and other minerals, as agate and carnelian, are chiefly composed of silica, small quantities of other substances being present which give them their peculiar colours. Silica is also called silicic acid, and is a compound of oxygen with an element called silicon. When in the pure state, silica is a white powder; if heated it does not melt, except the heat be extremely

intense; but when sand or flint, finely powdered, is mixed with caustic soda, or with carbonate of soda, and is then heated, the silica melts, uniting with the soda. Potash may be here used instead of soda. There are also other substances which when mixed with silica will cause it to melt, such, for instance, as red lead.

Glass.—The compound formed by silica with substances of this kind is called glass. All glass, whether used for windows, or bottles, or looking-glasses, is made by heating sand with soda or potash, only that common window glass and plate glass contain lime as well; whereas decanters and tumblers, which are made of what is called flint glass, contain oxide of lead in addition to the sand and soda or potash instead of lime.

Glass is made on a large scale in glass pots or crucibles composed of fire-clay, and when the glass is thoroughly made, and a proper temperature is kept up, the glass is in a pasty state, and can then, by competent workmen, be blown into globes, or fashioned according to taste.

Sheet Glass.—Window glass is made in two ways; it is either blown or cast. Common window glass is blown first into the form of a cylinder, which cylinder is cut on the inside by a diamond through its length, and is then put into a furnace, where the glass softens, and is spread out upon a stone into a flat plate. Sheet glass, as it is called, is made in this way.

Plate Glass.—The manufacture of plate glass, however, is somewhat different. The pot containing the melted glass is taken out of the furnace, and the glass is poured upon an iron table, which has strips of iron along its sides, as deep as the glass is required to be thick, and while the glass is soft a roller is passed over it: the plate that is formed is rough: its surfaces are carefully ground, and it is afterwards polished. All glass, directly it is made into its required form, is put into an oven, which is heated to a high temperature, but not sufficiently high to soften the glass again.

Annealing.—The glass in this oven is allowed to cool gradually for the space of some hours; this process is called "annealing," and by it the glass is rendered tougher than it would be if it were allowed to cool suddenly. Common tumblers, as you know, frequently crack and fly in pieces when hot water is poured into them, and this is because the glass has not been cooled slowly—*i.e.*, has not been properly annealed.

Soluble Glass.—A very interesting kind of glass is made by heating together sand and soda or potash alone, without lime or red lead. This glass, when finely powdered and boiled, gradually dissolves in water, forming a substance which is known as silicate of soda or silicate of potash. If some of this solution of silicate of soda be treated with hydric chloride, and if the solution be strong, a precipitate will be thrown down: if this precipitate be care-

fully washed, dried, and heated to a high temperature, it will become a white powder, and this white powder is pure silica. Before the drying, while the precipitate is still like a jelly, it can be dissolved by boiling it in hydric chloride; but if the white powder be heated to redness for some time it cannot then be so dissolved by hydric chloride.

You can easily prove that glass is softened by heat by holding a piece of glass tubing in a gas-flame. It will become soft, and you can bend it to any form you desire, or, when soft, if you pull the glass tube with both hands in opposite directions, you can draw it out into fine threads, and each of these threads will be a tube, which you can easily prove by breaking off a piece of the thread about three or four inches long, and inserting the end of it into a coloured liquid, the coloured liquid will rise in the tube by what is called capillary attraction.

If you hold the pointed end of one of the pieces of tube, after drawing it out, in the gas-flame for a short time, the little hole which was left in it, after drawing out, will be closed up, and then if you make that end of the tube soft by holding it still longer in the flame, and then remove it and blow into it quickly and gently, you will be able to produce a small glass globe.

CHAPTER XV.

ON APPARATUS.

THIS little book would not be complete, as far as it goes, unless some hints and directions were given about obtaining the materials for, and the method of constructing, the apparatus used in the various experiments described. In the experiment, Fig. 1, a retort-stand, a beaker glass, a Bunsen lamp, and india-rubber tubing are used. A thermometer is also placed in the beaker glass. The prices of apparatus, and where they can be obtained will be given at the end of this chapter.

Fig. 2.—A flask is employed, a cork, a piece of glass tube, and a spiral condenser in addition to a Bunsen lamp and a retort-stand.

First as regards Corks generally.—If a common cork is used, you will have to bore a hole or holes in it; this is done with what is called a "rat-tail file," which is a tapering circular file about five inches long. In using the file, first wet it, also wet the cork, which hold with the finger and thumb of the left hand, and press the point of the file, held in your right hand, against the part of the top of the cork where you wish the hole to be; give your

right hand a rotatory motion, and press the file against the cork, and it will gradually pass through it. Here the point to be aimed at is to keep the file perfectly straight, so that the hole in the cork may not slant towards the side. When you have pierced the cork, take out the file, and again wet it, and work it through the same hole, but insert the file at the bottom end of the cork. Always make the hole rather smaller than the tube or rod which is to be fitted into it. A little practice in boring holes in corks will soon make you expert at it. India-rubber corks can be bought with holes in them. These are more expensive than ordinary corks, but for apparatus which is often in use they are in the end cheaper.

On Cutting and Bending Glass Tube.—To cut glass tube of moderate diameter, only a triangular file is necessary (the triangular file should be about 4 or 5 inches long, and in its thickest part each side should be about $\frac{1}{4}$-inch wide). First wet the file, then hold the tube with the first finger and thumb at the place where you wish to cut it; draw the file sharply (but do not press *too* hard, or you may break the tube) two or three times backward and forward, while one of its edges is pressed on the glass; if pressed against the thumb-nail of your left hand the file will be kept on the same place on the glass; the file will mark the glass, it will not cut through it. Take the tube in both hands, the scratch being between them, and the hands being

an inch or two on either side of it, then gently attempt to bend the tube, and it will break across at the file-mark. The motion given to your hands should be *rather* smart. Here, again, after two or three trials you will be able to do it perfectly. Always in breaking tube, in putting tube through corks, or corks into flasks, hold the glass in a thick cloth; very serious accidents often happen by neglecting to do this. The writer has lost sensation and partial use of a finger by a glass tube breaking and passing into his finger, because he did not use a cloth to hold the tube; it is even better to hold both the glass and cork in cloths.

How to pass a Tube through a Cork.—First wet the cork and the tube, hold the tube in the right hand, enveloped in a cloth, and the cork between the left thumb and first finger; give the tube a rotatory motion when its end is entering the hole in the cork; press gently, keeping up the rotatory motion, and the tube will gradually pass through the cork; *never* press hard, *never* hurry the operation —mind the hole should be always a little smaller than the tube. In cutting larger tubes, say those of one inch diameter, and of considerable thickness, you must first make the cut with a file, but larger and deeper than in cutting a small tube; then heat a piece of glass rod in a gas-flame till it is soft, then rapidly press the hot soft glass into the cut in the tube, and you will generally find the tube divide into two parts. The ends of the tube where you

cut them are sharp at their edges; in order to round them, hold them (*i.e.*, the ends) in a gas-flame till they are red-hot and soft, keep them there for a minute or two, and the edges will become round and smooth; they will not then cut your fingers, and they will pass through corks much more easily.

To bend a glass tube, hold it in both hands, place it in an ordinary gas-flame; keep turning it round by twirling it between the thumbs and first fingers of your two hands; also pass it slightly from right to left through the flame, but always keeping part of it, which has been heated, in the flame. The tube will gradually get soft; when this happens, quickly remove it from the flame, and bend it; but this bending must be done gently, and you must never try to bend it after it ceases to yield freely to pressure; if you do, it will most certainly break. If you cannot bend it sufficiently with one heating, heat it again, and repeat the bending process. *Never* bend the tube *in* the flame. If you follow these rules, a little practice will soon enable you to make good bends.

Fig. 3.—Here what is called a "clip" is used (it looks like a retort-stand, but it is not), also a test-tube. The sizes and prices of test-tubes and clips will be given at the end.

Fig. 4.—Two test-tubes, a clip, a glass dish, and a galvanic battery.

Fig. 5.—The bottle here used is called a Woulfe's

bottle. It is rather expensive. You can substitute for it (and it answers quite as well) a bottle fitted up as shown in Fig. 31. It is well with such a bottle to use an india-rubber cork with two holes in it; the funnel is a tubulated or thistle funnel, and the stem of it should project almost twelve inches above the cork; the other tube

FIG. 31

FIG. 32.

can be either straight or bent, or of any convenient shape. You can take out one tube, and put in any other at pleasure.

Fig. 6.—This is called a wash bottle. A cheaper and equally useful form of it is given in the accompanying diagram (Fig. 32).

Here there are two tubes, one larger than the other. The larger passes through the cork, and is permanent; the smaller passes through it, and can be lifted in and out. The end of the smaller tube projects further into the bottle than that of the larger fixed tube. Bottles of this kind you can make yourselves after you have had a little practice at apparatus-making, and they will not cost a quarter the price of Woulfe's bottles. I nearly always use them in preference to Woulfe's bottles.

Fig. 7.—The connections, D D D, are made with small pieces of india-rubber tubing. It is best to wet the tubing before putting it on—it goes over the glass more easily. The ends of the edges of the tubes ought always to be rounded by holding them in a gas-flame as already described.

Fig. 8.—The flask here shown is a common Florence oil flask. Such flasks answer perfectly well. A common cork is employed, which is better than india-rubber, as the flask sometimes gets very hot. In choosing Florence flasks, get those which are thin at the bottom; those that are thick in that part *often* crack. In order to cleanse a flask from oil, wash it with a strong solution of common washing soda, or with a solution of caustic soda. When clean, dry it carefully. The best way to dry a flask or bottle is as follows:—*Carefully* warm it over a lamp, moving it about in all directions, so that it may become equally heated. The moisture in it

will be converted into steam. Take a piece of glass tube about 18 inches long; while the bottle is hot put one end of the tube into it, and put the other end into your mouth, and suck. You will thus draw the steam out, and so dry the bottle. *Remember* this must only be done with *clean* bottles. In this figure the vessel of water into which the gas passes is shown as transparent. This is only done that you may see the arrangement. An earthenware vessel does quite as well. The price of a Griffin's trough will be given at the end, but a sixpenny earthen glazed pan does very well.

Fig. 9.—P S is a deflagrating spoon, and the bottle shown is a two-quart wide-mouth stoppered bottle. A quart bottle is large enough. Never put too much phosphorus in the spoon. A piece as large as a sweetpea seed is large enough for a quart bottle. Mind that S is so arranged that it comes near the middle of the bottle. If it is too near the sides, it will most likely cause the bottle to break. Always dry the phosphorus carefully with filter or blotting paper, and do not forget the precautions already given about handling phosphorus. When gases are collected over water in wide-mouthed stoppered bottles, the stoppers should be greased, also the neck of the bottle, with tallow; when this is done, the stopper can be more easily placed in the bottle when its mouth is under water, and it can be more easily removed when you want to put in the deflagrating spoon, as it will not stick.

Fig. 10.—In making this experiment it is better to use a stoppered bell-jar. Grease the stopper as just described. The bell-jar has no bottom, therefore when it is full of oxygen you should place a plate in the collecting-trough in the water, and pass it under the bell-jar. There will be water in the hollow part of the plate when it is removed, and the bottom of the bell-jar standing in this water, the gas will not escape. The reason I recommend this is because hot particles drop from the iron wire, and if a bottle with a bottom is used, falling on it, they often crack it.

I need not comment on the intervening figures.

Fig. 14.—Here the test-tube should be filled with mercury, and the delivery-tube from the ammonia apparatus should be placed under the test-tube, just as if the mercury were water, and the gas will bubble up and displace the mercury. The piece of charcoal should be held between the finger and thumb of the right hand, and be put into the mercury, and held under the mouth of the test-tube. It should be then released, and it will pass up into the test-tube. The charcoal should be made small enough to go easily into the tube, and should be well dried over a Bunsen flame before it is used.

Fig. 15.—In fitting up this apparatus, a bottle, such as I have described, may be used instead of a Woulfe's bottle. You had better buy the bulb B until you are sufficiently expert to blow one for yourself. The hard glass tube should be longer

than that shown in the diagram: if it is too short, the corks will burn. I mean the corks used to stop its ends, through which the tubes from D and G pass. You can use two ordinary Bunsens, or three, instead of the arrangements shown; but they will require to be carefully arranged.

Fig. 16.—In all cases where glass troughs are used, earthenware ones will do as well.

Fig. 17.—A can be made by getting a piece of glass tube sufficiently wide, and heating it, and when soft, drawing it out; you can then cut the narrow drawn-out part to the length you require, after bending it; or you may cut it off before the bend, and couple it to a piece of bent glass tube with an india-rubber junction; or you can use a common medicine bottle, first cuting off the bottom evenly. This you can do by making a piece of thick iron rod ($\frac{1}{4}$-inch thick at least) red-hot; then, while red-hot, place it on the side of the bottle where you wish to cut it; the glass there will get very hot. Touch it quickly with your finger, which you must first make wet. The glass will crack. Then heat the iron again, and place it, while red-hot, at the end of the crack, and draw it gently along in the direction in which you wish the crack to go. If the crack ceases to follow it, make the iron hot as before, and repeat the operation. In this way you will be able to lead the crack round the bottle. Then into the neck of the bottle put a cork, and through it a tube, joining it with B. You

should have two or three inches between the top of the flame and the cork. You can make U-tubes by bending straight glass tube. The tube should be at least $\frac{3}{4}$-inch diameter, but you can buy them. The prices will be given.

Fig. 26.—Wire gauze (price given at end of book).

Fig. 27.—Prices of retorts are given at the end of the book. In putting the hydric sulphate into the retort remove the stopper, and pour it in through a funnel, the tube of which reaches nearly to the bottom of the retort, so that none of the hydric sulphate may run down the neck of the retort. Also be careful, in putting in the crystals of potassic nitrate, that none go into the neck of the retort. The paper used here should be blotting paper or filter paper, for these absorb water. The receiver may be a small flask. *No cork should be put into its neck, as shown in the diagram.* The retort-neck should be loose in it.

Fig. 28.—B is a "safety funnel." This you must buy, as it is difficult to make. The end of the safety funnel should *not* dip into the liquid in the flask A; but you should pour some oil of vitriol into the funnel, so as just to fill the lower bend in it. The oil of vitriol should just come into the bulb of the funnel: it should not fill it.

CHAPTER XVI.

I CANNOT lay too much stress on the importance of working out the following calculations. No useful knowledge of Chemistry can be obtained if such exercises be neglected. Chemical changes are exact and definite, and the student cannot too early learn by *practice* the proportions in which substances, whether elements or compounds, act upon one another; and the best way to do so is by working out such simple calculations as the following. It will be well to work out the questions in order as the chapters are studied.

QUESTIONS FOR CALCULATION.

As the answers are given, it is most desirable that teachers should see that they are reasoned and worked out by their pupils.

1. Some water is decomposed, and yields 3 measures of oxygen: what measure of hydrogen does it yield?

Ans. 6 measures.

2. How much oxygen by measure must be mixed with 50 measures of hydrogen so as to form a mixture similar to that which is got by the decomposition of water by the galvanic battery?

Ans. 25 measures.

3. What is the weight of 5 measures of oxygen if an equal quantity of hydrogen weighs 5?

Ans. 80.

4. When water is decomposed, we get 2 measures of hydrogen and 1 measure of oxygen: what is the weight of the oxygen compared with the hydrogen?

Ans. 16 to 2, or 8 to 1.

5. How much hydrogen by weight can be obtained from 49 parts by weight of oil of vitriol?

There are two methods by which calculations of this kind can be worked out:—

1st method—

98 parts of oil of vitriol give 2 parts of hydrogen.
1 part ,, gives $\frac{2}{98}$ of hydrogen.
49 parts ,, give $\frac{2 \times 49}{98} = 1$ of hydrogen.

2nd method (ordinary rule of three),

Parts of oil of vitriol.		Parts of hydrogen.		Parts of oil of vitriol	
98	:	2	: :	49	:

$$\begin{array}{r} 49 \\ 2 \\ \hline 98)\ 98 \\ \hline 1 \end{array}$$

1 part hydrogen.

Ans. 1 part of hydrogen.

6. How much hydrogen by weight can be obtained from 392 parts by weight of oil of vitriol?

Ans. 8 parts of hydrogen.

7. How much oil of vitriol will yield 50 parts by weight of hydrogen?

Ans. 2,450 parts.

8. How many pounds of hydrogen can be obtained from 294 pounds of oil of vitriol?

Ans. 6 pounds.

9. How many ounces of oil of vitriol are required to yield 12 ounces of hydrogen?

Ans. 588 ounces.

10. What weight of zinc is required to act on 1,176 parts of oil of vitriol in order to set all the hydrogen free?

Ans. 780 parts of zinc.

11. How much hydrogen by weight can be evolved from oil of vitriol by the action of 260 parts by weight of zinc?

Ans. 8 parts by weight of hydrogen.

12. It is required to make 16 grains of hydrogen: how much zinc must be made to act on oil of vitriol to obtain them?

Ans. 520 grains of zinc.

13. How much zinc sulphate is left when 28 grains of hydrogen have been evolved from oil of vitriol by the action of zinc?

Ans. 2,254 grains of zinc sulphate.

14. It is required to set free 138 grains of hydrogen from water: what weight of sodium must be used to do it?

Ans. 3,174 grains of sodium.

15. What weight of water can be decomposed by 138 ounces of sodium?

Ans. 108 ounces of water.

16. How much potassium can set free 5 grains of hydrogen from water?

Ans. 195 grains of potassium.

17. How much potassium will it take to decompose the same weight of water that can be decomposed by 20 grains of sodium?

Ans. $33\frac{21}{23}$ grains of potassium.

18. What weight of chlorate of potash is required to give off 240 ounces of oxygen?

Ans. $612\frac{1}{2}$ ounces of chlorate of potash.

19. What weight of oxygen can be obtained from 1,225 grains of potassic chlorate?

Ans. 480 grains of oxygen.

20. A certain weight of black oxide of manganese contains 96 parts by weight of oxygen: how much of that oxygen can be obtained free when the black oxide is properly heated?

Ans. 32 parts.

21. 1 pound, 2 ounces, and 18 grains of water are decomposed by the galvanic battery: what weight of oxygen and of hydrogen will be obtained?

Ans. 2 ounces 2 grains of hydrogen, and 16 ounces 16 grains of oxygen.

22. It is required to form 72 grains of water by the direct union of oxygen and hydrogen: how much oil of vitriol must be used to make the necessary quantity of hydrogen?

Ans. 392 grains.

23. If 5 measures of oxygen and 12 measures of hydrogen be mixed together in a suitable bottle, and if a light be applied, an explosion will take place, and water will be formed. Will all the hydrogen unite with the oxygen? If not, how much of it will go to form water?

Ans. 10 measures.

24. If you obtain all the oxygen from 245 grains of chlorate of potash, and all the hydrogen from 588 grains of oil of vitriol, and cause them to unite, how many grains of water will be formed?

Ans. 108 grains of water.

25. Some hydrogen gas is coming out of a gas-burner, and you apply a light to it, it will burn in the air: when 320 grains of it have been burned, how much oxygen will it have united with from the air, and how much water will be formed?

Ans. 2,560 grains of oxygen and 2,880 grains of water.

26. A measure of hydrogen weighs 20 lbs.: what is the weight of an equal measure of carbonic acid gas?

Ans. 440 lbs.

27. If 50 lbs. of carbon are burnt in oxygen, what weight of carbonic acid gas will be formed?

Ans. $183\frac{1}{3}$ lbs. of carbonic acid.

28. How much oxygen is required to unite with 20 lbs. of carbon so as to form carbonic acid?

Ans. $53\frac{1}{3}$ lbs. of oxygen.

29. How much carbon can unite with 150 lbs. of oxygen so as to form carbonic acid?

Ans. $56\frac{1}{4}$ lbs. of carbon.

30. How much more carbon do 2 quarts of carbonic oxide contain than 1 quart of carbonic oxide?

Ans. Double the quantity.

31. A measure of hydrogen weighs 10 lbs.: what is the weight of an equal measure of carbonic oxide?

Ans. 140 lbs.

32. How much carbon must be burned in 4 lbs. of oxygen to form carbonic oxide?

Ans. 3 lbs. of carbon.

33. A small quantity of oxygen is passed over a large quantity of red-hot charcoal: how much carbon will it unite with?

Ans. $\frac{3}{4}$ times its own weight of carbon.

34. What quantity of oxygen must unite with 90 lbs. of carbon to form carbonic oxide?

Ans. 120 lbs. of oxygen.

35. If two litres of carbonic acid be passed over red-hot charcoal, how much carbonic oxide will be formed?

Ans. 4 litres.

36. When a litre of carbonic oxide is burned in air, how much carbonic acid is formed?

Ans. 1 litre.

37. About what measure of oxygen is contained in 32 litres of atmospheric air?

Ans. $6\frac{2}{5}$ litres.

38. What measure of nitrogen must be mixed with 50 litres of oxygen to form a mixture nearly like that of air?

Ans. 200 litres.

39. The nitrogen which fills a gas-holder weighs 50 grammes: what weight of hydrogen will be required to fill it?

Ans. $3\frac{4}{7}$ grammes.

40. The hydrogen in a bottle weighs $\frac{1}{2}$ of a gramme: what weight of nitrogen will fill the same bottle?

Ans. 7 grammes.

41. If 5 measures of hydrogen weigh 5 grammes, about what will be the weight of 5 measures of atmospheric air?

Ans. 72 grammes.

42. When a measure of atmospheric air weighs 72 grammes, what weight of carbon will have to be burned in it so as to form carbonic acid?

Ans. 6 grammes of carbon.

43. When a measure of air weighs 72 grammes, what weight of hydrogen is required to unite with its oxygen to form water?

Ans. 2 grammes of hydrogen.

44. What volume of hydrogen is required to unite with the oxygen in 20 litres of air so as to form water?

Ans. 8 litres of hydrogen.

45. A litre of air is passed over a large quantity of red-hot charcoal: how much carbonic oxide is formed?

Ans. $\frac{2}{5}$ of a litre of carbonic oxide.

46. When charcoal is burned in excess of air, if 50 litres of carbonic acid are formed, how much air has been consumed?

Ans. 250 litres of air.

47. If 20 measures of air be passed over red-hot copper, how many measures of gas will they lose?

Ans. 4 measures of oxygen.

48. What volume of air must be mixed with 25 litres of marsh gas so as to cause them to explode when a light is applied?

Ans. 250 litres of air.

49. What weight of carbonic acid, and what weight of water are formed when 16 grammes of marsh gas are burned in oxygen or air? (N.B.—The word exploded might be used, for exploding is a sudden burning.)

Ans. 44 grammes of carbonic acid, and 36 grammes of water.

50. What weight of marsh gas, when burned, yields 176 grammes of carbonic acid, and 144 grammes of water?

Ans. 64 grammes of marsh gas.

51. What measure of oxygen is required to burn 10 litres of marsh gas? (N.B.—Just consider how much air is required.)

Ans. 20 litres of oxygen.

52. How much nitrogen by measure is there in 150 litres of nitrous oxide gas?

Ans. 150 litres of nitrogen.

53. What weight of oxygen is consumed when a piece of charcoal is burned so as to unite with all the oxygen in 11 grammes of nitrous oxide gas?

Ans. 4 grammes of oxygen.

54. 132 parts by weight of nitrous oxide are decomposed by burning phosphorus in them: what volume of nitrogen is left?

Ans. 6 measures of nitrogen.

55. What volume of oxygen is there in 50 litres of nitrous oxide gas?

Ans. 25 litres.

56. If a measure of hydrogen weighs 10 grammes, what will be the weight of an equal measure of nitrous oxide?

Ans. 220 grammes.

57. What weight of nitrous oxide can be obtained from 80 grammes of ammonic nitrate?

Ans. 44 grammes.

58. What weight of nitrous oxide can be obtained from 5 grammes of ammonic nitrate?

Ans. $2\frac{3}{4}$ grammes.

59. How many measures of nitrous oxide can be obtained from 250 parts by weight of ammonic nitrate?

Ans. $6\frac{1}{4}$ measures.

60. What weight of nitrous oxide, and what weight of water are formed when $6\frac{2}{13}$ grammes of ammonic nitrate are heated?

Ans. $3\frac{5}{13}$ grammes of nitrous oxide and $2\frac{10}{13}$ grammes of water.

61. How much hydric nitrate can be obtained from 30 grammes of potassic nitrate?

Ans. $18\frac{72}{101}$ grammes of hydric nitrate.

62. How much hydric nitrate can be obtained by the action of 15 grammes of hydric sulphate or potassic nitrate, if the residue be hydro-potassic sulphate?

Ans. $9\frac{9}{14}$ grammes of hydric nitrate.

63. How much hydric sulphate is required to decompose 50 grammes of potassic nitrate?

Ans. $48\frac{52}{101}$ grammes of hydric sulphate.

64. How much hydric sulphate must be used with 9 grammes of potassic nitrate to form hydric nitrate; potassic sulphate being left as residue?

Ans. $4\frac{37}{101}$ grammes of hydric sulphate.

65. What weight of hydro-potassic sulphate is formed when $121\frac{1}{5}$ grammes of potassic nitrate are decomposed by hydric sulphate?

Ans. $163\frac{1}{8}$ grammes.

66. How much potassic sulphate is formed by the action of 14 grammes of hydric sulphate on potassic nitrate?

Ans. $24\frac{6}{7}$ grammes.

67. What weight of potassium is able to replace all the hydrogen in 392 grammes of hydric sulphate?

Ans. 312 grammes of potassium.

68. What weight of sodium is able to take the place of the potassium in the last question?

Ans. 184 grammes of sodium.

ON THE VOLUME OF GASES.

Under certain circumstances 11·2 or $11\frac{1}{5}$ litres of hydrogen weigh one gramme: for my present purpose it is not necessary to explain what these circumstances are, and the explanation would involve a greater space than can be allowed in a small book like this. It is enough to state here that when 11·2 litres of hydrogen weigh 1 gramme, 11·2 litres of oxygen weigh 16 grammes, 11·2 litres of nitrogen 14 grammes, etc. If you refer to the composition of "Nitrous Oxide," page 64, you will find it stated that two measures of nitrous oxide contain two measures of nitrogen to one measure of oxygen. It is clear, therefore, that if there are together three measures of the constituent gases, and two measures of the compound, there must be a condensation of volume of the nitrogen and oxygen, when they form nitrous oxide gas. Suppose the oxygen to weigh 16 grammes, and to measure 11·2 litres; the nitrogen, which weighs 2 (14) grammes, will measure 2 (11·2) litres, and the nitrous oxide formed by them will measure 2 (11·2) litres, that is, the same as the nitrogen measures; and the nitrous oxide will weigh 44 grammes. If you refer to the "Weight and Composition

of Carbonic Acid," page 31, you will see that a measure of carbonic acid weighs 22 times as much as an equal measure of hydrogen. Suppose 1 gramme of hydrogen measures 11·2 litres, then 22 grammes of carbonic acid will measure 11·2 litres, and 2 grammes of hydrogen will measure 2 (11·2) litres, and 44 grammes of carbonic acid will also measure 2 (11·2). But the composition of this carbonic acid by weight is 12 grammes of carbon and 2 (16) or 32 grammes of oxygen. Now 16 grammes of oxygen measure 11·2 litres, when 1 gramme of hydrogen occupies the same volume; therefore 2 (11·2) of carbonic acid contain 2 (11·2) litres of oxygen. If you take the weight in grammes of any of the compound gases (treated of in this book), you will find that they measure 2 (11·2) litres, when 1 gramme of hydrogen measures 11·2 litres, and therefore, if you want to find out the weight on any of these compound gases as compared with hydrogen, you have to add together the weights of the constituents of the compound, and divide by 2.

Questions on Ammonia.

69. What weight of nitrogen is there in 68 parts by weight of ammonia?

Ans. 56 parts of nitrogen.

70. What weight of hydrogen is there in 153 parts by weight of ammonia?

Ans. 27 parts of hydrogen.

71. Ammonia gas is 8½ times as heavy as hydrogen: when 11·2 litres of hydrogen weigh one gramme, what is the weight of 78·4 litres of ammonia gas?

Ans. 59·5 grammes.

72. When 11·2 litres of hydrogen weigh one gramme, what will 34 grammes of ammonia gas measure?

Ans. 44·8 litres.

73. What measure of hydrogen and what measure of nitrogen is there in 2 (11·2) litres of ammonia gas?

Ammonia gas is $8\frac{1}{2}$ times as heavy as hydrogen; 1 gramme of hydrogen measures 11·2 litres; $8\frac{1}{2}$ grammes of ammonia measure 11·2 litres; therefore $2 (8\frac{1}{2}) = 17$ grammes of ammonia measure 2 (11·2) litres. In 17 grammes of ammonia there are 3 grammes of hydrogen and 14 grammes of nitrogen (see page 71), but 3 grammes of hydrogen, 3 (11·2) litres and 14 grammes of nitrogen measure 11·2 litres.

*** In 2 (11·2) litres of ammonia gas there are 3 (11·2) litres of hydrogen, and 11·2 litres of nitrogen.

N.B.—You here see that these measures of nitrogen and hydrogen are, in ammonia gas, condensed to half their volume.

74. What volume of hydrogen is there in 112 litres of ammonia gas?

Ans. 168 litres.

75. What volume of nitrogen is there in 95 litres of ammonia gas?

Ans. 47·5.

PRICES OF APPARATUS.

Beakers (in sets) of 3 to hold		3 oz. to 6 oz.,	1s.	the set
,, ,, 6	,,	1 oz. to 9 oz.,	2s. 6d.	,,
,, ,, 5	,,	3 oz. to 18 oz.,	2s. 6d.	,,
,, ,, 5	,,	$1\frac{3}{4}$ oz. to 12 oz.,	2s.	,,
Retort Stand		2s. 6d.		
Bunsen		1s. 6d.		
Ditto, with rose burner ...		2s. 6d.		
Thermometer		5s. 6d.		

Flasks,	1 oz. to $2\frac{1}{2}$ oz.,	3d.	each,
,,	4 oz.	4d.	,,
,,	6 oz.	6d.	,,
,,	16 oz.	8d.	,,
,,	1 pint	9d.	,,
,,	$1\frac{1}{2}$ pints	1s.	,,

India-rubber Corks, 2d. to 6d. each
Test Tubes, per dozen, 1s. to 1s. 6d.
Straight Clips, 1s. 8d., hinged 3s.
Double Clips vary in price from 3s.
Galvanic Batteries vary; suitable ones for the experiment described, can be obtained from £2.

Woulfe's Bottle,	2 necks,	$\frac{1}{2}$ pint, 1s.
,,	,,	1 pint, 1s. 4d.
,,	,,	$1\frac{1}{2}$ pint, 1s. 6d.

Wide-mouthed Bottles (not stoppered), 3d. to 4d. each.
U Tubes, 6d. to 8d. each
Griffin's Trough, 2s. 9d.
Wire Gauze (per foot), 1s. 6d.
Funnels, from 3d. each.

Berlin Dishes,	$2\frac{3}{4}$ in.,	5d.
,,	$3\frac{1}{2}$ in.,	7d.
,,	4 in.,	11d.
,,	$4\frac{1}{2}$ in.,	1s. 1d.
,,	6 in.,	1s. 7d.

Safety Funnel, 9d. to 1s.
Deflagrating Spoon, 1s.

Oxygen Bell-jar	(wide mouth)	5	in. high	× 3,	1s.
,,	,,	7	,,	4,	2s.
,,	,,	9	,,	5,	3s.
,,	,,	11	,,	6,	4s.

Wide-mouth Stoppered Bottle (quart), 1s. 6d.
Test-tube Stand, 1s. 2d.
Triangular File, 7d.
Rat-tail File, 7d.
Spirit Lamp, 1s. to 2s. 6d.

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ERRATUM.

The title of Chapter VIII. (p. 63) should read "Oxides of Nitrogen;" not "Oxides *and* Nitrogen."